ON THE LOWER PALEOZOIC STRATIGRAPHY OF THE NORTHERN PENINSULA OF MICHIGAN

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Harold Fordyce Crooks

ENTITLED ON THE LOWER PALEOZOIC STRATIGRAPHY OF THE NORTHERN PENINSULA OF MICHIGAN

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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Recommendation concurred in:*

Committee on Final Examination*

*Required for doctor's degree but not for master's.

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ON THE LOWER PALEOZOIC STRATIGRAPHY OF THE NORTHERN PENINSULA OF MICHIGAN.

INTRODUCTION.

The area under consideration is that portion of the northern peninsula of Michigan bounded by Lake Superior on the north, Lake Michigan, Little Bay de Noc and Big Bay de Noc on the south, St. Marys River on the east, and a north-south line joining the towns of Rock River and Rapid River on the west. This portion of the peninsula is underlain by rocks of lower Paleozoic age, representing the Cambrian, Ordovician and Silurian systems. The strata of Cambrian age are sandstones belonging to the Croixian series; those of Ordovician age are soft arenaceous limestones, shales and shaly limestones belonging to the Canadian, Mohawkian and Cincinnatian series; while those of Silurian age are dolomites, limestones and magnesian limestones belonging to the Alexandrian, Niagaran and probably Cayugan series. Rock exposures are generally few, tho outcrops are in places extensive, as at the Pictured Rocks near Munising, and the rocky promontories of the southern shore, as at Burnt Bluff. Glacial drift material is nowhere deep, but is in general deeper in the eastern than in the western part of the area. It is the low gradient of the streams that accounts for the paucity of rock outcrops - great areas in the interior of the region being muskegs, while small swamps and shallow lakes are everywhere common.

During the summer of 1916 the writer spent several weeks in the field studying the stratigraphic relations of the above mentioned rocks, paying especial attention to those of Cincinnatian and lower Silurian age, in an attempt to correlate these strata with rocks belonging to corresponding series to the south, and with those of

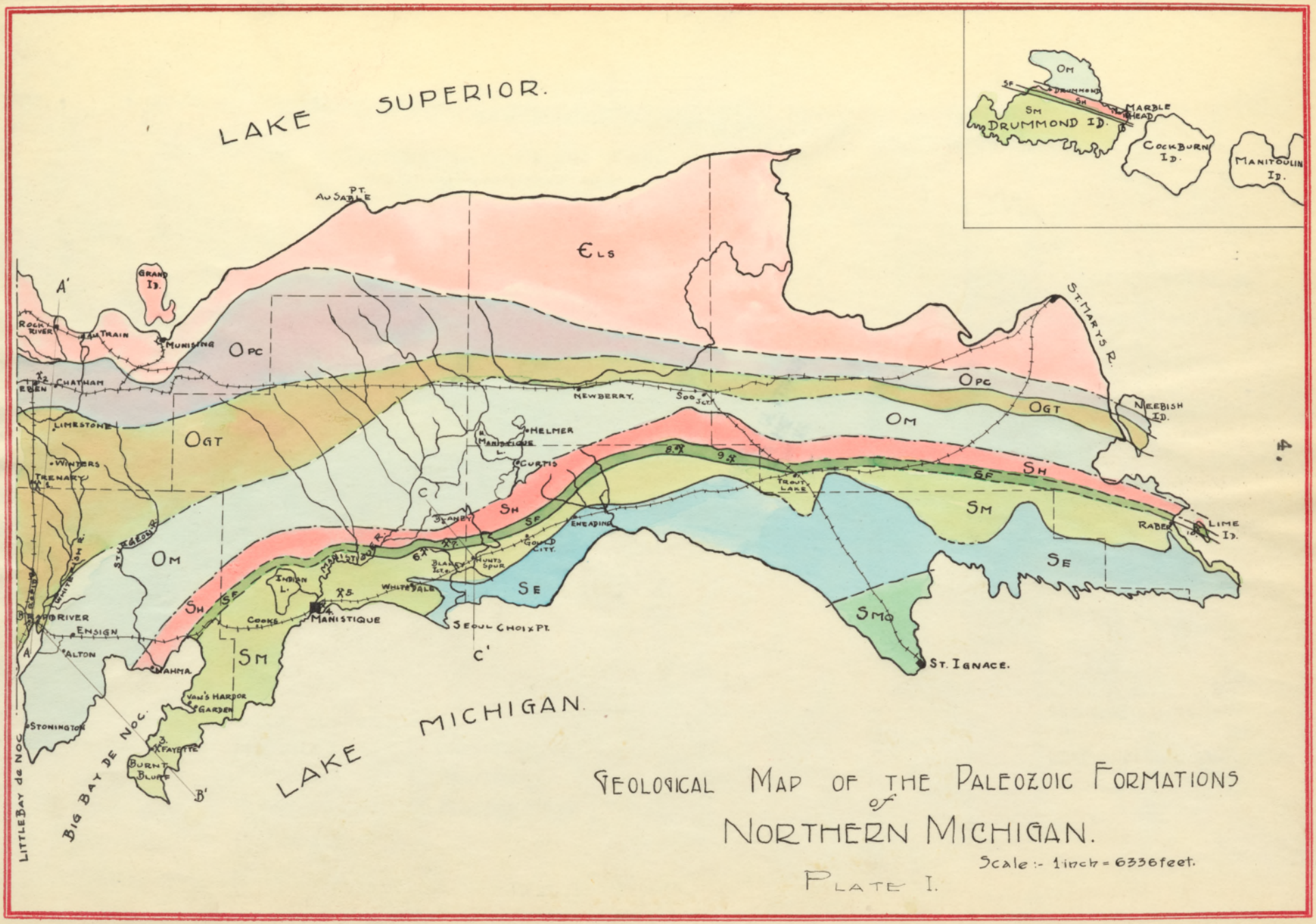
Manitoulin Island in Georgian Bay to the east. Lithologically the rocks of these series in northern Michigan are of fairly uniform texture,color,and composition thruout their extent,and are very similar to corresponding dolomites and limestones in Wisconsin. From the descriptions of strata on Manitoulin Island their correspondence with the Cincinnatian and early Silurian rocks of Michigan is less close.

Acknowledgements.

To Dr.T.E.Savage the writer gladly acknowledges his great indebtedness for encouragement,aid in the prosecution of the field work,and assistance in the identification of the fossils. Mr.Geo. M.Ehlers,of the University of Michigan aided in the loan of fossils collected by him which identified by the writer clinched the determination of the Alexandrian series in northern Michigan. Thanks are also due to the Michigan Geological Survey and to Mr.R.A.Smith, of that organization,for maps,and records of deep wells in this portion of the state. The Chief Engineer's office of the Minneapolis,St.Paul and Sault Saint Marie Railroad was kind enough to furnish a list of elevations above mean tide level of their stations in the area to be considered. Free use has been made of the literature and where no acknowledgement has been made following a citation,such will be found in the bibliography at the end of this paper.

DISTRIBUTION OF STRATA.

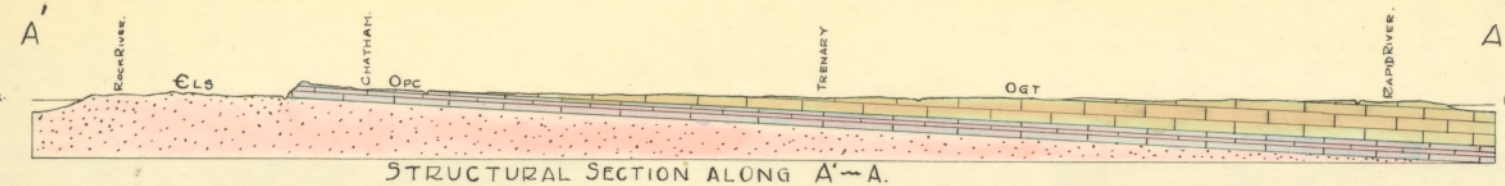
Rocks of Paleozoic age are distributed thruout the upper peninsula of Michigan in a succession of more or less parallel, arcuate belts;the oldest formation outcrops along the border of Lake Superior,while the youngest is exposed farthest south;the arrangement being,for analogy,much like that of a deck of cards slipped one over the other and tilted slightly. In the east part of the area the dip is toward the south while in the west it is toward the southeast. Dips are always moderate,never exceeding three or four degrees (40 - 60 feet per mile);the strike varies with the locality but is in general in an approximately east-west direction. The relation of these strata to those of the lower peninsula is such that they form the north rim of a saucer-like basin the center of which is north of Lansing;the depression being partly Ordovician and partly post-Ordovician in age.



Geological Map of the Paleozoic Formations of Northern Michigan.

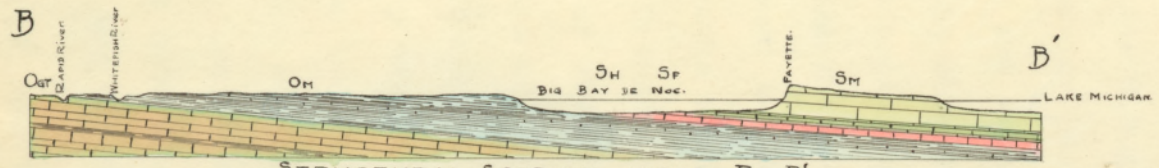
Scale :- 1 inch = 6336 feet.

Plate I.



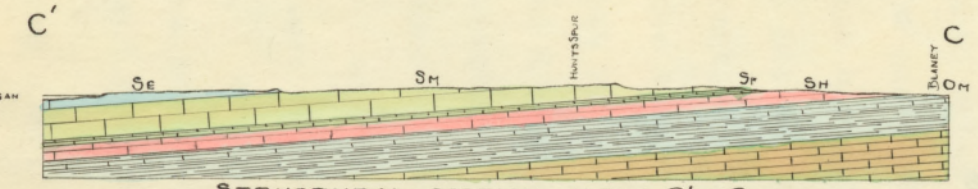
STRUCTURAL SECTION ALONG A'~A.

Scale:- Horizontal and Vertical 1 inch equals 2112 feet.



STRUCTURAL SECTION ALONG B~B'

Scale:- Horizontal and Vertical 1 inch equals 2112 feet.



STRUCTURAL SECTION ALONG C'~C.

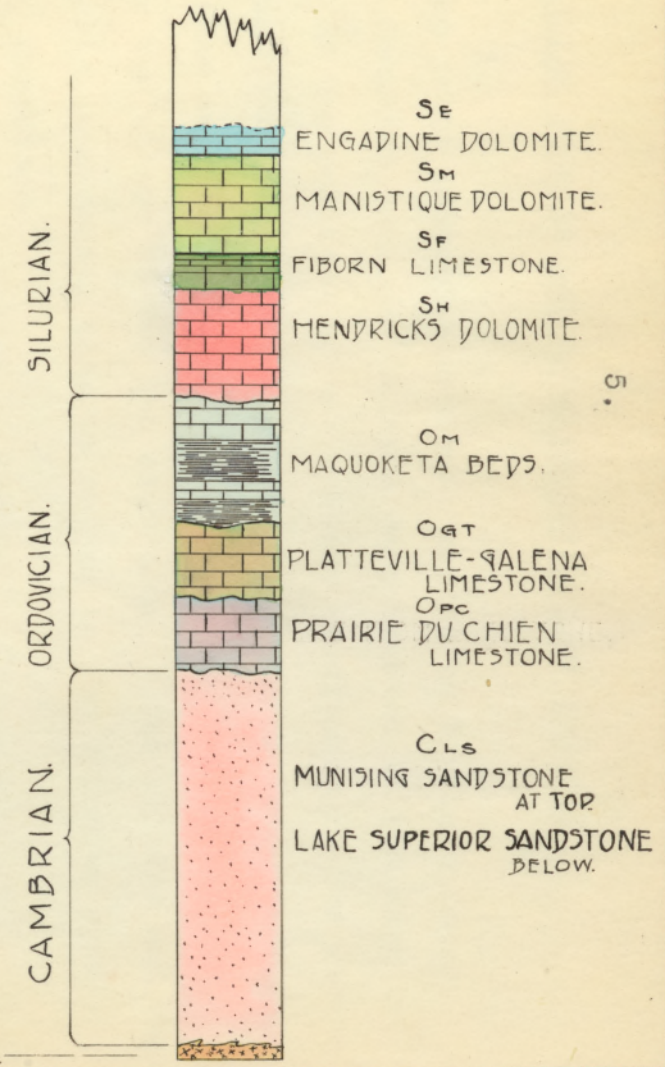
Scale:- Horizontal and Vertical 1 inch equals 1056 feet.

STRUCTURE SECTIONS.

PLATE II.

LOCATION OF QUARRIES.

1. Trenary.
2. Eben.
3. Fayette.
4. Manistique.
5. Marblehead.
6. Boyle's.
7. Blaney.
8. Hendricks.
9. Fiborn.
10. Lime Island.
11. Dickinsons.
12. Seamans.
13. Marble Head.



EARLIER STUDIES AND INTERPRETATIONS OF STRATA.

In the years 1840-50,occasional papers by Bayfield,Logan, Murray,Locke,Houghton,Owen,and Jackson were devoted in the main to the question of the position of the Potsdam sandstones in the stratigraphic column;some thot these sandstones rested on limestones,and others that they overlaid granites;some regarded them of Old Red sandstone age and others of New Red sandstone. Tho all did not thus err,the majority considering them to belong to the Silurian system as defined by Murchison.

In 1851,the U.S.geologists,Foster and Whitney,[1] made a report on the "Lake Superior Land District". This report included chapters on the lower and upper Silurian systems in this region by James Hall,together with physiographic notes by Desor and Whittelsey. Hall,the paleontologist of the party,studied in reconnaissance manner the succession of strata exposed along the Lake Michigan shore from Drummond Island to Little Bay de Noc,correlating in all cases with the rocks in New York,and dividing them into Chazy,Birdseye,Black River,Trenton,and the shales and limestones of the Hudson River group,all of which he put in the lower Silurian,placing in the upper Silurian the Clinton and Niagaran as he had distinguished them. In considering the limestone and dolomitic phases of the rocks immediately overlying those of the Hudson River group,he investigated exposures on the north and east sides of Drummond Island, Big Bay de Noc,the eastern shore of Green Bay,and down the Wisconsin River still farther west. He distinguished two series of strata differing both in fauna and lithology which he referred respectively to the Clinton and Niagaran of New York. Tracing

(1) Foster,J.W.,and Whitney,J.D., Lake Superior,vol.II,p.153,

the former rocks westward from Drummond Island to Big Bay de Noc,he states that along the base of the cliff at Burnt Bluff,he found at water level,layers of precisely the same character and characterized by the same fossils as those at Drummond Island,such as a species of Leperditia,an Avicula,and Murchisonia sublata. These beds at the base were observed to gradually pass upward into the thicker beds of the Niagaran group. The beds at the eastern extremity of Drummond Island mentioned above are but a few feet in thickness and consist of a shaly limestone immediately overlying strata of the Hudson River group,and in turn overlain by Niagaran limestones;it was these beds he considered to be of Clinton age. He thot that the Clinton rocks,continuous thruout the peninsula,were everywhere conformable with the overlying Niagaran,a correct conclusion,but at variance with that expressed by Alexander Winchell who later studied the geology of this region.

Winchell[4],in 1873,thot he recognized at the Middle Bluff section on Garden Peninsula "a persistent mixed conglomerate bed eight to twelve inches or more in thickness separating the Clinton from the Niagara".

Dr.Carl Rominger[3],of the Michigan Geological Survey was the next to make a contribution on the subject,which he did in 1871. Rominger agreed with the previous determinations of geologists,in regard to the Potsdam,Calciferous,Chazy,Trenton,and the Hudson River group in this region,and cited additional exposures and gave lists of fossils which he collected in support of these interpret-

(3),Rominger,C.,Mich.Geol.Survey,vol.I,pt.III,p.49

(4),Winchell,A.,Sketches of Michigan,1872,p.54.

ations. He takes issue with previous definitions of the Clinton group,stating that so far as his experience went,the three fossils from the three foot exposure in Dickinsons quarry on Drummond Island are confined to the lower strata,while those above are filled with Niagaran species. Thus he restricted considerably the limits of the Clinton as previously defined.

Nothing further was done on the geology of this region until 1904,when A.C.Lane[25],published a paper on the waters of the peninsula, in which he considered the Paleozoic rocks in a very cursory manner, but offered nothing new from a stratigraphic standpoint.

In 1904,I.C.Russell[8],made an examination of the surface geology and mapped the Lake Michigan border.

In 1908,Lane[26],gave a very good summary of the knowledge of the Paleozoic rocks in Michigan,but did not make any contribution to the subject. He recognized that the Medina and Rochester were absent,but continued to recognize the New York Clinton,or possibly its equivalent,at the base of the Niagaran. He mentions visiting limestone caves in the vicinity of the present Fiborn quarry,but thot them to be in Niagaran rock.

In 1912,R.A.Smith[20]discussed the "Occurrence of Oil and Gas in Michigan",giving many useful well data,but made no advances in the line of stratigraphic knowledge.

In 1916,Smith[5]published a paper on the limestone resources

(25),Lane,A.C.,Mich.Geol.Survey,Ann.Rept.1903,p.113-167.

(8), Russell,I.C.," " " " " .1904,p.39-115,2 maps.

(26),Lane,A.C., " " " " " .1907,p.97-143,1 Map.

(20),Smith,R.A., " " " ,Pub.14,Geol.Ser.11,p.231-246,1912.

(5) ,Smith,R.A., " " " , " 21, " " 13,p.108-383,1915.

of Michigan in which he recognized the succession of the Ordovician as given by his predecessors,but for the Silurian he made some important changes.

GENERAL STRATIGRAPHY OF THE AREA.

THE CAMBRIAN SYSTEM.

The oldest rocks exposed in the upper peninsula of Michigan are of upper Cambrian age and are called by the Michigan Geological Survey the Lake Superior sandstones. They consist of thick bedded red and white sandstones which occur along the shore of Lake Superior, extending for a short distance inland. They are considered of Croixan age and the equivalent in part to the Potsdam sandstone of the New York section. Rominger[3] subdivided these rocks into two members, the lower one composed entirely of red ferruginous sandstone he called the Lake Superior member, and the upper, essentially white, sandstone he called the Munising member on account of its good development in the vicinity of Munising.

From the vicinity of Marquette to east of Munising, the prominent Lake Superior sandstone is the most prominent feature along the shores of the lake. In the city of Marquette there are several quarries from which this stone is taken for building purposes. At the state park on Presque Isle, in the environs of the city, the relation of the sandstone to the underlying rocks of Algonkian age is beautifully exposed on the northwest side of the "Island", where it rests disconformably on tilted, pink Kona dolomite, and a few hundred feet farther northwest it overlies crumpled and truncated Mona schist. At the latter locality the sandstone is fine grained, massive, and made up of alternating layers of red and white sand rock which shows but indistinct bedding, and cleaves along joints better than along bedding planes. The gradation from white to red, highly ferruginous

(3), Rominger, C., Geol. Survey of Mich., vol. I, pt. III. 1871.

layers is not always sharp,the general tendency being towards a gradual transition from red to white to red. The red rock is made up of slightly rounded,practically colorless quartz grains,which are firmly cemented in a hematite matrix very red in color. The nature of the cement of the white layers was not ascertained.

Where Rock River empties into Lake Superior there are several small reefs of the lower sandstone some of which rise above the water level. The rocks here have the characteristic color and texture of the Lake Superior sandstone,and are overlain by a light yellowish sandstone which appears to have been deprived of its color by wave action and leaching. Here,instead of the alternation of color seen at Presque Isle,the rock contains small white areas about a quarter of an inch in diameter,and nearly circular in cross-section. Miller[10] has observed similar spherical masses in the Old Red sandstone of Devonian age in England,and explains them as follows:"The dye has disappeared in circular patches of various sizes,from an eighth of an inch to a foot in diameter,and the original white has taken its place. The reducing agent was organic matter;the uncolored patches are no surface films,for when cut at right angles,their depth is equal to their breadth;and in the center of the sphere we generally find traces of the organizm in whose decay it originated". In the field the writer broke many sandstone fragments containing such white areas and found at the center of only one of them a small brownish-gray nucleus which may have been organic. The white layers and spots occurring in this sandstone are thought generally to result from impregnations of clay at the time of deposition.

(10),Miller,Hugh,The Old Red Sandstone.

Unconformity between Lake Superior sandstone (above) and Kona dolomite (below). Presque Isle, Mich.

Fig.1.

View of this unconformity taken to the east of that in Fig.1.

Fig.2.

Lake Superior sandstone at mouth of Rock River.

Grand Island in distance.

Fig.3.

Cross-bedding in Lake Superior sandstone, east of Brownstone,

Mich.

Fig.4.

From the lake nearly to the station of Rock River,on the Duluth,South Shore and Atlantic Railroad,the Rock River flows over red sandstones similar to those exposed near its mouth. In a railroad cut at the flag station called Brownstone,one-half mile east of Rock River station,Lake Superior sandstone 18 inches thick is exposed to an elevation of 657 feet,capped by 10 inches of alluvium containing limestone pebbles. A little farther (1 1/4 miles) east, a thickness of 18 feet of prominently cross-bedded sandstone is seen. In this outcrop white clay streaks become prominent and the rock gradually loses the red color so that the upper 5 feet of the bed below the red sandstone is white. This whitish sandstone is quartzose,and is characterized thruout by the presence of flat,green, clay-like pebbles which lie with their longest diameters parallel to the bedding planes. The overlying red sandstone is 4 to 5 feet thick,and does not show the white layers very prominently,but it contains small,hard,flat,magenta-red pebbles of clay-like hematite. The presence of the green pebbles suggests that oxidation controlled by bedding planes has here been the chief agent which caused the change from red to green. Grimsley[37] cites a similar color relation of the rocks at Medicine Lodge,Kansas,where red shales overlie greenish gypsum,the color of the latter being due he thinks to ferrous iron.

The bed of Rock River for the entire distance from its mouth to a short distance west of the wagon bridge across the river three miles north of Chatham,is on Lake Superior sandstone similar to that at Brownstone,but having a more siliceous cementing material;the hematite pebbles are also a conspicuous feature on freshly broken surfaces,have been weathered out of exposed areas leaving the rock

with a pitted appearance. An exposure of these rocks in sec.22,T 46 N,R 21 W,furnished the following section:

Section of strata exposed in sec.22,T 46 N,R 21 W.

		Thickness, feet.
4.	Alluvium and gravel.....	2
3.	Prairie du Chein Sandstone,white,calcareous,quartzose,in layers 1 to 4 inches thick,with intercalations of soft,micaceous,gray shale in bands 1/16 - 1/8 inch thick. Strike N 70 W,dip 5 SW.....	50
2.	Alluvium covered interval.....	24
1.	Lake Superior sandstone Sandstone,reddish-brown,with few white clay streaks,and numerous soft,flat, red,hematite pebbles. Exposed in bank to bed of river elevation 643 feet.....	2
		78

Fourteen miles above the mouth of the Taquamenon River,according to Rominger[3],there is exposed in a series of cascades in the east branch of the river,a bed of white,ripple-marked sandstone composed of little water-worn,glistening quartz grains,imbedded in a siliceous cement,the whole having a thickness of 50 feet. Four miles farther up the river a second cascade of 59 feet occurs over a light colored, soft,friable sandstone,interstratified with arenaceous gray shales which are locally red and micaceous. At Grand Island,on the west

(3),Rominger,C.,Geol.Surv.of Mich.,vol.I,pt.III,p.85.

side of Trout Bay, arenaceous dolomite of Prairie du Chien age overlies a ledge of white sandstone 75 feet thick, which stands 50 feet above the Bay. Just across the bay, to the east, a thickness of 15 to 20 feet of bluish-red, massive sandstone is exposed a short distance above the level of the water. Farther west, on the Laughing Whitefish River, Rominger found a calcareous sandstone with intercalated, shaly layers immediately overlain by a brownish-red, sandstone. The following section is exposed:

Section of strata exposed along the Laughing Whitefish River.[3]

		Thickness, feet.
7.	Prairie du Chien limestone Sandstone, with casts of Pleurotomaria...	
6.	Sandstone, white, soft, massive, standing in vertical walls.....	50
5.	Sandstone, white, highly calcareous, soft, thin bedded, the layers separated one from the other by narrow seams of blue shale.....	75-100
4.	Lake Superior member Sandstones, light colored, soft, in thick ledges, containing seams of quartz pebbles, followed by a few feet of dark red, coarse conglomerate. Thickness uncertain.....	
3.	Sandstone, red or speckled, hard, coarse grained, in layers up to 4 and 5 feet in thickness, aggregating.....	15- 20
2.	Sandstone, red, fine grained, more or less argillaceous, in layers from 1 to 3 feet in thickness, with seams of red shale....	12
1.	Sandstone, hard, thin-bedded, micaceous, alternating with arenaceous shales. The	

(3), Rominger, C., Geol. Surv. of Mich., v.I, pt.III, p.88.

sandstone layers from 1/2 to 1 inch in thickness. Some of their surfaces are even, others undulating and ripple-marked. The interstratified shales are spotted with round white dots. These beds continue downward beneath the lake. Visible thickness..... 25

165- 207

Judging from these data the relations of the sandstones in these three widely separated localities, the writer is inclined to the belief that the Munising sandstone, the white sandstone at Grand Island, said by Smith[12] to have a thickness of 250 feet and to lie above about 1200 feet of Lake Superior sandstone in the vicinity of Munising, is not a continuous deposit above the latter member, but represents a local deposit of possibly eolian origin, similar to that accorded by Grabau[13] to the Croixan sandstone, of which he says "this northern Potsdam (Croixian) sandstone shows evidence of continental origin in pre-marine time by the occurrence of well-marked torrential cross-bedding".

(13), Grabau, A.W., Principles of Stratigraphy, p.642, 729. 1913.

THE ORDOVICIAN SYSTEM.

Detailed Stratigraphy of the Canadian Series.

Rocks belonging to the Canadian series in Michigan are divided into the Prairie du Chien limestone at the base,overlain by the Hermansville limestone;the latter having been shown by Bayley[38] to compose the tops of hills in the Menominee district. The thickness of this series is given by Smith[12] as "from 100? to 250 feet".

The Prairie du Chien sandstones and limestones form a prominent north facing cuesta,80-90 feet high,along the south border of outcrop of the Lake Superior sandstone. This cuesta is flat-topped and has a gently dipping back slope. The escarpment extends east and west of Chatham for a distance of thirty miles,gradually losing itself in the sand plains east of Grand Maris,but becoming more prominent towards the west where it reaches an altitude of 1059-1150 feet as at Lawson,Rumley and Carlshend[11];diminishing in thickness as it swings to the south so that at the Wisconsin line it is far from being the conspicuous feature it is farther north. Towards the east it assumes a northeast trend to south of Au Train where it forms the falls of the Au Train River,125 feet in height.

At Eben,a small quarry is operated in this formation which there consists of a coarse,sandy,and in places oolitic,yellowish, unfossiliferous dolomite,in layers 8 to 20 inches thick,a total of 4 feet being exposed. Altho no outcrops,save those mentioned,are

(11),Leverett,F.,U.S.G.S.,Water Supply Paper 160.

exposed in the immediate vicinity of Eben or Chatham,the Prairie du Chien rocks are apparently near the surface as is shown by the following well records:

Log of well at Poor Farm,Chatham.

		Thickness, feet.	Depth, feet.
5.	Alluvium.....	5	5
4.	Shell rock. (Prairie du Chien.....	5	10
3.	Limestone,white,sandy....	10	20
2.	Dolomite,gray.....	12	32
1.	Limestone,white.....168		200

Record of well at Chatham Cemetary,in sec.27,T 46 N,R 21 W.

3.	Alluvium.....	1	1
2.	Sand.....	19	20
1.	Limestone,grayish,sandy..	40	60

Record of well at Chatham Town Hall.

2.	Alluvium.....	4	4
1.	Limestone,white.....137		141

Record of well at Eben Junction School-house.

2.	Alluvium.....	1	1
1.	Limestone,white,sandy....150		151

In a small quarry in this formation three-fourths of a mile south of Chatham,at an elevation of 872 feet,the rocks appear to be similar to those exposed at Eben quarry,and are likewise unfossiliferous.

Generally speaking the Prairie du Chien limestones and dolomites are exposed over an arcuate belt extending from St.Marys

River to the Menominee River. Outcrops are few in the eastern area, but Rominger describes extensive exposures on Neebish and Encampment d'Ours Islands in the St.Marys and also at the falls of Au Train River, which latter he says, "in a series of stair-like descents, crosses nearly 100 feet of Prairie du Chien rocks." Farther west, in the vicinity of Menominee, this formation crosses the state line into Wisconsin and extends south to the latitude of Madison as a low-lying cuesta to the west of the Galena-Platteville lowland and the more prominent Niagaran escarpment.

Good exposures of the Prairie du Chien are seen along the Menominee River where the following section was made by Rominger[3]:

Section of Prairie du Chien strata exposed at Grand Rapids on the Menominee River.

		Thickness, feet.
6.	Limestone, fine grained, crystalline, even bedded, in thin layers, with clay partings. (These disappear under the drift).....	2
5.	Limestone, nodular, with concentric structure resembling masses of Stromatopora.....	3
4.	Dolomite, compact, partly arenaceous and partly of oolitic structure.....	2
3.	Limestone, fine grained, argillo-areno, banded with red stripes or blotches, with admixed mica plates, evolves a strong bituminous smell under the blow of a hammer. Some leaf-like bodies of possible organic origin.....	3
2.	Limestone, dolomitic, hard, together with oolite beds.....	4
1.	Sandstone, white, coarse grained, of varying hardness, with interstratified bands of arenaceous shale; surface of layers strongly ripple-marked. Numerous limestone fragments in upper sandstone..	5
		19

Altho no unconformity has been noted between the Prairie du Chien and the overlying Trenton a great sedimentary break is shown by the absence, save locally, of the St.Peter sandstone. Chamberlin and Salisbury[18] note that in Wisconsin there is an unconformity between these two formations, and on account of this fact and from other considerations they raise the question whether the Prairie du Chien should be classed with the Cambrian rather than with the Ordovician.

The relations of this formation in the vicinity of Escanaba will be seen from the log of a deep boring given below[39]:

Log of the Louis N.Schemmel Test Hole No.2.

Location:- SW cor.SW quarter of NE quarter of sec.28, T 39 N, R 23 W, about four miles west of Escanaba. Drilled for iron ore in 1914. Samples taken every 5 feet, and at every change. Samples furnished by L.N.Schemmel, and examined by L.P.Barrett and R.A.Smith of the Mich.Geol.Survey. No samples taken down to 300 feet.

	Thickness, feet.	Depth, feet.
55.Platteville-Galena limestone		
Sandstone, white, very calcareous.....	10	310
54. Limestone, white, sandy.....	5	315
53.Prairie du Chien limestone		
Limestone, white, argillaceous, with much red oxid. (This red oxidised horizon probably represents the eroded land surface of the Prairie du Chien upon which the St.Peter sandstone was deposited. The latter apparently fills hollows and valleys in the former).....	4	319
52. Limestone, very white, with some red oxid and sand.....	1	320

(18), Chamberlin and Salisbury, Geology, v.II, p314.

(39), Smith, R.A., Personal communication.

51.	Limestone,white,sandy.....	10	330
50.	Limestone,grayish white.....	5	335
49.	Limestone,white,with some quartz sand.....	5	340
48.	Limestone,white to very light buff.....	5	345
47.	Limestone,white to very light buff,with some quartz sand.....	5	350
46.	Sandstone,white.....	15	365
45.	Sandstone,white,with some very white dolomite slow effervescence.....	15	380
44.	Dolomite,white,sandy.....	5	385
43.	Dolomite,white,with some sand.....	8	393
42.	Dolomite,white.....	3	396
41.	Dolomite,white,sandy,pyritic.....	4	400
40.	Dolomite,white,very sandy.....	2	402
39.	Sandstone,white,very calcareous,nearly half dolomitic limestone,some pyrite,hard....	1	403
38.	Limestone,dolomitic,white,soft,20% pure white quartz sand.....	1	404
37.	Dolomite,yellowish-white,sandy,15% pure white quartz sand.....	11	415
36.	Dolomite,yellowish-white,soft,sandy,10% pure quartz sand.....	3	418
35.	Limestone,white,medium hard,dolomitic,with a little colorless quartz sand and brown ferruginous matter.....	7	432
34.	Limestone,white,dolomitic,hard,with small amount of brownish-gray ferruginous matter.....	3	435
33.	Dolomite,light buff,hard,with much red-brown iron oxid,very little fine white quartz sand.....	3	438
32.	Limestone,white,dolomitic,hard,with small amount of fine white quartz sand.....	7	445
31.	Limestone,white,dolomitic,hard,with about 5% fine,colorless quartz sand.....	5	450

30.	Limestone,very light buff,dolomitic,hard,a little fine,white quartz sand and particles of brownish-red iron oxid.....	5	455
29.	Limestone,reddish-buff,sandy,dolomitic,hard, with much brownish-red iron oxid,about 10% colorless quartz sand.....	5	460
28.	Limestone,light buff,dolomitic,hard,with a reddish-brown cast due to considerable iron oxid.....	2	462
27.	Limestone,reddish-buff,dolomitic,sandy,hard, with considerable reddish-brown iron oxid,and quartz sand.....	3	465
26.	Limestone,red,sandy,dolomitic,hard,with a large amount of brownish and orange-red iron oxid.....	5	470
25.	Limestone,reddish-buff,sandy,hard,much iron oxid,some fine,white quartz sand.....	1	471
24.	Limestone,reddish-buff,dolomitic,hard,with much iron oxid in brownish-red particles very little sand,limestone fragments largely white.....	1	472
23.	Limestone,reddish-buff,dolomitic,hard,with much iron oxid,limestone fragments varying from white to yellow and red, a little white quartz sand.....	1	473
22.	Limestone,very red to buff,dolomitic,hard, large amount of iron oxid,limestone particles white to red and yellow.....	1	474
21.	Limestone,very red to buff,dolomitic,hard, still larger amount of iron oxid,limestone particles white to yellow and red with the two latter colors predominating	1	475
20.	Limestone,deep buff to red,dolomitic,hard, with a very large amount of iron oxid, some white quartz sand.....	2	477
19.	Limestone,very buff to red,dolomitic,softer than No.20,large amount of iron oxid, limestone particles chiefly yellow and orange colored,some white quartz sand...	3	480
18.	Limestone,light buff to red,dolomitic,hard, small amount of iron oxid.....	2	482
17.	Limestone,buff to red,dolomitic,hard.....	3	485

16.	Limestone,very dark red,soft,dolomitic.....	1	486
15.	Limestone,very dark red,dolomitic,soft.....	4	490
14.	Limestone,red,highly ferruginous,very sandy, pyritic,residue of about 25% of white pyritic sand.....	5	495
13.	Limestone,red,highly ferruginous,very sandy, residue more than 25% of white and very pyritic sand.....	2	497
12.	Limestone,reddish-gray,sandy,much less iron oxid,pyrite and sand than in No.13. Limestone particles white,red and gray..	3	500
11.	Limestone,gray,sandy,pyritic. Limestone particles gray and white with some reddish	2	502
10.	Limestone,grayish-buff,sandy,little sand but considerable iron oxid	3	505
9.	Limestone,reddish-buff,very sandy,residue of 30% white quartz sand ,minute pyrite crystals.....	4	509
8.	Lake Superior ? sandstone		
	Sandstone,reddish-buff,ferruginous,calcareous residue of 60% of white quartz sand,some pyrite.....	1	510
7.	Limestone,light red,ferruginous,very sandy, residue of about 40% fine white quartz sand.....	5	515
6.	Sandstone,reddish-white,considerable iron oxid,but little calcareous matter.....	3	518
5.	Sandstone,reddish-white,calcareous,ferruginous,essentially a sandstone.....	1	519
4.	Sandstone,white and red,calcareous,hard.....	4	523
3.	Sandstone,white and red,calcareous,hard.....	2	525
2.	Sandstone,red and white.....	2	527
1.	Sandstone,red and white,less ferruginous than Nos.2 and 3.....	4	531

Detailed Stratigraphy of the Mohawkian Series.

The Mohawkian series as exposed in Michigan consist of "Trenton limestone" according to the Michigan Geological Survey,but in the opinion of the writer this series is represented by the Platteville limestone overlain by the Galena limestone. Nowhere in the Upper Peninsula is the lower member of the series,the St.Peter sandstone,exposed. The thickness of the rocks of the Mohawkian series varies from 100 feet in the east[12] to 250 feet in the west. The variability of its thickness may be seen from well records given on succeeding pages.

The Saint Peter Sandstone.

The presence of the St.Peter sandstone in Michigan has not been certainly determined. It has never been observed in outcrop, and its presence can only be determined from detailed records of deep borings;such records from the vicinity of the Wisconsin line and near Escanaba indicate the presence of this sandstone. Thruout Wisconsin the St.Peter is very irregular in distribution,seeming according to Chamberlin[6] to occupy erosion hollows in the Prairie du Chien limestone and in general being thicker toward the southern part of the state than farther north. These irregularities increase from Dodge County northward and by the time the Michigan line is reached it is only occasionally that it is noted. The formation has been observed within 4 miles of the Michigan line where it has a thickness of 20 feet. In Michigan it apparently likewise occupies hollows in the Prairie du Chien especially in the Menominee-Escanaba region and around Little Bay de Noc;hence it is not often encountered in well borings. Near Escanaba a test hole was put down from which

samples were taken every two feet,or less. Smith[9] found a large thickness of very red ferruginous sandstone that he called St.Peter, and which he thought was derived from highly oxidised material from the old upper Cambrian land-mass. If this interpretation is correct and it seems reasonable to think that such is the case,the St.Peter sandstone was derived from decomposition of older sandstones over exposed areas of upper Cambrian strata.

The Platteville-Galena Limestone.

Unconformably overlying the Prairie du Chien limestone and above the St.Peter sandstone when that formation is present,are limestones,shaly-limestones and dolomites grouped under the significant name of Platteville limestone,or the "Trenton" in part of early writers. In discussing these deposits in Wisconsin,Chamberlin divides the "Trenton" into four formations[9]: the lower buff and lower blue beds,and the upper buff and upper blue beds,with an aggregate thickness of 125 feet. In addition he considered them to be overlain by the Galena dolomite having a thickness of 125 to 165 feet. Bassler[45] following Ulrich, places the lower buff and lower blue beds in the Platteville;the upper buff and upper blue beds in the Decorah shale member;both the Platteville and the Decorah being included in the Beloit limestone. Above these formations comes the Galena dolomite. For Michigan this grouping holds so far as the Platteville and Galena are concerned,save that here the Galena is a limestone.

Lane[17] in 1908 used the classification given last above,but

(9),Smith,R.A.,Personal communication of May 25,1916.

(6),Chamberlin,T.C.,Geology of Wis.,vol.II,p.289. 1873.

(45),Bassler,R.S.,U.S.Nat.Museum,Bul.92,vol.II,chart.

questions its correctness. The present Geological Survey of Michigan has also adopted it without citing any paleontological evidence in its support.

Chamberlin and Salisbury[18] state that the Trenton or Platteville limestone as recognized in the north-central states may correspond to the Lowville and Black River beds of the New York section, while the Galena is about the equivalent of the New York Trenton. Grabau suggested that the typical New York Trenton in the narrower sense is represented in the upper peninsula of Michigan by what has been interpreted as Utica shale. This does not seem probable in view of the fact that at present no deposits of Utica age are known in this region,all of the Cincinnatian series being considered of Maquoketa (upper Richmondian) age.

Thruout the area under discussion the rocks of the Mohawkian series occupy with those of the Cincinnatian series the position of a lowland to the north and west of the prominent Alexandrian-Niagaran escarpment,the surface expression of both being the result of glacial and pre-glacial denudation. In this respect they are very similar to rocks of like age in Wisconsin and on Manitoulin Island.

Low exposures of the Platteville beds were seen south of Chatham in the banks of a small creek crossing secs.9 and 10,T 45 N, R 21 W,at an elevation of 877 feet. These outcrops were scattered, and the rocks were apparently unfossiliferous,consisting of buff slabs of sandy dolomite. South of this place,in the vicinity of Limestone and Winters,exposures occurred at infrequent intervals along the roadside,and the numerous bowlders of various sizes that

(18),Chamberlin and Salisbury,Geology,vol.II,p.314,1907.

were scattered over the fields,showed that the formation was near the surface. Three-quarters of a mile south of the town of Trenary, along the south bank of the Whitefish River,a small quarry covering possibly two acres has been worked in rocks of this formation to a depth of 11 feet. The following section was made in the south side of the quarry:

Section of Platteville limestone exposed at Trenary quarry.

(Elev.of floor of quarry 846 feet.)

		Thickness, feet.	in.
5.	Alluvium.....	1	2
4.	Limestone,yellowish,sandy,with strong effervescence.....	3	0
3.	Limestone,steel-blue,calcareous,shaly,with many bryozoa.....		8
2.	Limestone,bluish,with blue and white streaks, very compact,without fossils.....	4	0
1.	Limestone,yellowish,soft and friable,strong effervescence,containing many shells of Orthis tricenaria;floor of quarry....	2	0
		11	0

The thinner blue member,No.3 above,varied in thickness as seen along the south face of the quarry,being much thinner toward the west than near the east side. These rocks effervesce strongly with cold,dilute hydrochloric acid,have an earthy,conchoidal fracture,and show distinctly alternating light and dark laminae. The fossils marked "B" in Table I,were collected from these beds.

As noted in the above section,the blue limestone is underlain by a sandy,buff limestone containing drusy calcite,and an abundance of silicified fossils,principally Orthis tricenaria. The

fossils marked "A" in Table I came from this bed. Rominger[3] thot that the fossils he collected in this vicinity were characteristic of the Birdseye limestone, which corresponds to the lower part of the Platteville. A comparison of the fauna collected from these strata by the writer, with that listed by Chamberlin[6] for the Platteville of Wisconsin, and with the fossils collected by Rominger from strata of similar age, throws very little light on the problem of correlation since there are in the lists no species of restricted vertical range, most of them persisting thruout the entire thickness of beds. Doubtless these strata represent the lower part of the "Trenton" or Platteville limestone, but owing to the paucity of exposures it is doubtful whether they can be correlated very far either to the east or west.

The Whitefish River flows almost its entire course over rocks of Platteville-Galena age which dip gently to the southeast at the rate of 30 to 40 feet per mile. There are occasional small exposures along its low banks. Rominger[3] observes that in sec.2, T 43 N, R 20 W, the bed of the river is formed of hard, dolomitic ledges, and that from angular blocks of this rock along the bank he collected Echinoencrinites sp. which was very common, together with the following forms:

Streptelasma corniculum	Orthis tricenaria
Various bryozoa	Plectambonites sericeus
Orthis pectinella	Calymene senaria

These fossils are very similar to those belonging to the

(3), Rominger, C., Geol. Surv. of Mich., v.I, pt.III, p, 63

(6), Chamberlin, T.C., Geol. of Wis., v.II, pp.293-304.

"Trenton"* as he had observed it on Day's River near Maple Ridge, Mich.

Along the bed of Rapid River for a distance of three to five miles above Little Bay de Noc, are continuous exposures of what the writer interprets to be Galena limestone. In the rapids of the Whitefish River above the mill-pond the water runs over very coarsely crystalline, dolomitic layers which contain many siliceous veins and some few cavities in which petroliferous matter has accumulated. From these strata the following fossils were collected by Rominger[3]:

Crinoid stems	Rafinesquina deltoidea
Dalmanella testudinaria	Zygospira recurvirostra

Rapid River flows over hard, compact, buff limestone which is partially dolomitized and shows on the surface, peculiar fucoidal markings similar to those occurring in the Tribes Hill limestone of New York, and described by Van Tuyl[19] as "sinuous pipes of dolomite weathering in relief", and attributed to some organism of unknown affinities which "appears to have exercised a selective influence upon the dolomitization". Overlying this horizon and forming the banks of the river (see fig.5) is a limestone bed 4 to 5 feet thick. This is a hard, dense, crystalline, almost lithographic rock which according to Smith[5] shows on ananysis 81.98% $CaCO_3$. Dolomitization seems to have effected or to be effecting this stratum since a polished surface shows irregular patches of fine grained, lithographic rock surrounded, or partly surrounded by darker, softer, duller areas.

(3), Rominger, C., Geol. Surv. of Mich., v.I, pt.III, p.63.

* Probably Galena.

(19), Van Tuyl, F.M., Iowa Geol. Surv. v.XXV, pp.251-421, plate XX, 1914.

(5), Smith, R.A., Geol. Surv. of Mich., Pub. 21, geol. ser. 13, p.289.

Platteville-Galena limestone forming the bed of Rapid River.

Near Rapid River,Mich.

Fig.10.

Exposure of Maquoketa shales and limestones on Wisner Creek,east of Alton,Mich.

Fig.11.

The fossils from this bed are mostly similar to species listed by Chamberlin[6] from the Galena limestone of Wisconsin, but since none of them are guide fossils little correlation value can be placed upon them. The more common species from this horizon are indicated by "W" in Table II.

The record of wells in this vicinity furnish information concerning the thickness of both Platteville and Galena limestones. A well at Pickford[5] passed thru white "Trenton" (probably Platteville) limestone 275 feet thick to a depth of 800 feet, the elevation of the well being 670 feet*. The Neebish well on Neebish Island, in St. Marys River at the eastern extremity of the area, penetrated 190 feet of what is probably Platteville limestone; rock being reached below the drift at an elevation of 587 feet. At Gore Bay on Manitoulin Island the "Trenton" was struck at 331 feet and penetrated thru to a depth of 250 feet. A well drilled for the Cleveland-Cliffs Iron Co., five miles north of the town of Rapid River, by Mr. J. Scheska, and quoted by him, shows the following section:

Log of well of Cleveland-Cliffs Iron Co., north of Rapid River.

		Thickness, feet.	Depth, feet.
7.	Alluvium.....	2	2
	Platteville-Galena		
6.	Limestone, gray, hard.....	45	47
5.	Shale and soapstone, blue.....	40	87
4.	Limestone, gray.....	50	137

(6), Chamberlin, T.C., Geol. of Wis., v.II, p.294, 1873.

(5), Smith, R.A., Mich. Geol. Surv., pub. 21, geol. ser. 17, 289; 1915.

* The accuracy of this log is questioned. The thickness seems too great.

	Prairie du Chien and Cambrian		
3.	Granite(?),gray,(probably dolomite).....	50	187
2.	Sandstone,grayish-yellow.....	75	265
1.	Slate,(?)blue.....	208	473

Martin[14] states that the Galena limestone in Wisconsin is coarse grained and shaly at the base and is from 125 to 250 feet in thickness,while the underlying Platteville is sandy at the base and from 40 to 120 feet thick. Smith[12] thinks that along Green Bay the Platteville-Galena is 250 feet thick,while towards the east it diminishes to 100 feet or less in the St.Marys River region. In this connection a comparison of logs of wells given below is of value. The thickness of the Platteville-Galena estimated by the writer in traversing from the outcrops north of Trenary to Little Bay de Noc was 257 feet.

The following log shows the thickness of rocks of the Mohawkian series in the western portion of the area:

Log of the Louis N.Schemmel Test Hole No.1.

Location:- The general location of this hole is the same as that for hole No.2,given on page 21;the holes are 30 feet apart.

		Thickness, feet.	Depth, feet.
Elevation?			
	Pleistocene or glacial drift		
73.	Sand and "drift".....	10	10
72.	Quicksand.....	8	18
71.	Quicksand and broken limestone.....	12	30
70.	Quicksand,and finely comminuted limestone....	1	31
	Galena limestone		
69.	Limestone,white to light buff,dolomitic.....	18	49

68.	Limestone,blue-gray,argillaceous,pyrite at 125 feet.....	71	120
67.	Limestone,dolomitic,mixed bluish-gray and white.....	5	125
	Platteville limestone		
66.	Limestone,bluish-gray to light gray and white	20	145
65.	Limestone,dark gray to white,argillaceous, pyritic.....	15	160
64.	Limestone,gray and light buff,some bluish-gray shale.....	5	165
63.	Limestone,dolomite,and dolomitic limestone, yellowish to grayish-white,hard,finely crystalline.....	38	203
62.	Dolomite and dolomitic limestone,light gray, dense.....	15	218
	St.Peter sandstone and Prairie du Chien limestone		
61.	Dolomite and dolomitic limestone,white,sandy, with abundant colorless grains of quartz which in places form more than one-quarter of the rock,pyritic in places.....	47	265
60.	Limestone,white,sandy,with large amount of small,rounded,colorless quartz grains...	10	275
59.	Sandstone,white,pure,rounded colorless quartz grains.....	14	289
58.	Sandstone,white,pure,somewhat calcareous.....	5	294
57.	Limestone,white,dolomitic,sandy.....	7	301
56.	Limestone,white,sandy,dolomitic.....	4	305

TABLE I.

Fossils from the Platteville Limestone.

The fossils listed below were collected from Trenary quarry.

B. Escharopora angularis Ulrich.

B. Rhinidictya cf mutabilis Ulrich.

A. Streptelasma profundum Owen.

A. Streptelasma sp.

A. Orthis tricenaria Conrad.

B. Dalmanella achates Billings.

B. Rhynchotrema increbescens (Hall).

B. Plectambonites sericeus (Sowerby).

A. Strophomena incurvata (Shepard).

A. Strophomena cf trentonensis U.& S.

B. Strophomena sp.

A. Trochonema sp.

A. Trochonema sp.

B. Illaenus sp.

TABLE II.

Fossils from the Galena Limestone.

The fossils listed below were collected along the bed of Rapid River from Little Bay de Noc north two miles.

Cheirocrinus logani Billings.

Crinoid column segments.

W. Dalmanella testudinaria (Dalman).

Dinorthis sp.

W. Orthis tricenaria Conrad.

W. Plectambonites sericeus (Sowerby).

Strophomena incurvata (Shepard).

Strophomena billingsi W.& S.

Strophomena winchelli H.& C.

Strophomena cf trentonensis U.& S.

Strophomena sp.

Ecclioptérus sp.

Eccyliomphalus contiguus Ulrich.

Holopea conicula U.& S.

W. Hormotoma gracilis Hall.

Liospira abrupta U.& S.

Liospira sp.a.

Liospira sp.b.

Liospira sp.c.

Raphistoma modesta Ulrich.

W. Poterioceras apertum Whiteaves.

Illaenus cf americanus (Billings).

Isotelus maximus Locke.

Detailed Stratigraphy of the Cincinnatian Series.

Strata belonging to the Cincinnatian series in Northern Michigan have heretofore been thought to represent the Utica, Lorraine, and Richmond members as defined for the New York section. They occupy a position unconformable upon, and are exposed to the south and east of the area of outcrop of the Platteville-Galena limestone. They are also separated by an unconformity from the overlying Alexandrian series to the south. The thickness of this group varies from 350 to 450 feet as shown by the various well records. From a study of fossils collected in the Stonington-Little Bay de Noc region it is thot that these strata are to be correlated with, and considered a continuation of, the Maquoketa shales and limestones of Wisconsin.

The Maquoketa Formation.

All of the early writers on the upper Ordovician of Wisconsin attempted to correlate these shales and limestones with the Utica and Lorraine formations of New York. All the rocks included between the top of the Galena and the base of the Mayville limestone are of Maquoketa age, or are so considered at present, and are thot to be the equivalent of some part of the Maquoketa beds of Iowa and Illinois. In Wisconsin the Maquoketa, which includes greenish blue shales and shaly limestones, occupies a narrow belt to the west of the prominent Silurian escarpment, being wider at the south than at the north. Its most northerly exposure is six miles west of Sturgeon Bay, on the shores of Green Bay, where prominent ripple-marks, sun cracks, pyrite crystals, and truncated layers mark the disconformity which exists between these shales and the Alexandrian series. The relation of

this formation to the overlying Mayville limestone as well as the great variety of its constituent strata is well shown in the following section:

Section of the Maquoketa formation at Brick Yard,Wis.,six miles south of High Cliff.

	(Elev.of uppermost bed 930 feet.)	Thickness, feet.
	Mayville limestone	
7.	Limestone,in beds 1 to 3 feet thick, with many cavities.....	10
	Unconformity	
	Maquoketa formation	
6.	Grass covered interval,Maquoketa shale..	18
5.	Shale,soft,fossiliferous.....	12
4.	Grass covered interval with many limestone fragments,very fossiliferous.	91
3.	Shale,yellowish,with thin layers of limestone.....	5
2.	Shale,dark gray.....	15
1.	Limestone,dark gray,hard,shaly in places and fossiliferous,6 feet. Below this is shale,hard,dark gray,very pure,35 feet. Shale extends at least 7 feet below water level of Lake Winnebago.....	41
		192

On Manitoulin Island the formations between the Trenton and the top of the Ordovician are generally referred to the Cincinnatian series. The order of succession and characteristic fossils of these formations are:

Formations.	Thickness.	Characteristic fossils.
Upper Richmond.	50-60 ft.	Primitia lativia.
		Rhytimya kagawongensis.
		Ortonella hainesi.
Middle Richmond.	30-50 ft.	Beatricea undulata.
		Strophomena vetusta.
		Ceraurus meekanus.
		Cape Smyth Stromatocerum reef.
		Gore Bay Columnaria reef.
Lower Richmond.	40-50 ft.	Strophomena huronensis.
		Strophomena sulcata.
		Hebertella insculpta horizon.
Lorraine.	100 ft.	Whiteavesia pholadiformis.
		Modiolopsis concentrica in upper part.
Eden.	20-30 ft.	Interbedded limestones with
		Coeloclema communis.
		Dekayella ulrichi.
		Clays with
		Triarthus becki.
		Trinucleus concentricus.
Utica of New York.		Absent in Lake Huron area.
Collingwood.	20-30 ft.	Ogygites canadensis.

From a comparison of the above fossils with the list of Maquoketa forms from Michigan, given at the end of this chapter, it is seen that none of them are common to the two areas. This is significant not only in suggesting the absence of Maquoketa phase of

of the Richmond from Manitoulin Island,but it suggests that a barrier probably existed which separated these two sites of deposition. It is not known where the faunal change takes place,but it is thought that it may occur not far east of Curtis. It should be also noted that the fauna of the Cincinnatian strata in Northern Michigan differs markedly from that of the Maquoketa beds of Wisconsin. However,it is more closely allied to the latter than to the Cincinnatian strata of Manitoulin Island.

Ulrich in commenting on Lane's views regarding the presence of the Utica and Lorraine in Michigan,states that these formations do not outcrop,but that the "Trenton" is succeeded by the Maquoketa of Richmond age,with a hiatus between ~~the~~ equivalent to the Eden, Utica and Maysville of the Cincinnatian series. This view harmonizes in part with the above statements.

The Maquoketa formation in Michigan consists of soft shales and shaly limestones,and occupies a belt concentric with,and to the south of,the Platteville-Galena limestones and dolomites,upon which it is unconformable. It is likewise unconformable with,and lies to the north of the area of Alexandrian rocks in this region. It is well developed in the bluffs at Stonington,and in the low bluffs at the junction of Bill's Creek with the Whitefish River.

Smith[9] thinks that strata belonging to the Cincinnatian series in this region are to be included in the Rochester,Clinton, Medina,Cataract,Richmond,Lorraine,and Utica,but adds that some of them may be represented only locally,with some question as to the presence of the Clinton and Rochester. He may be right in regard to the presence of the Lorraine and Richmond in the eastern portion

of the area in the vicinity of St.Marys River,but it will be shown that there can be no correlation made with the New York section as he has suggested in the case of the first four formations for not only are they absent from Manitoulin Island,but in Michigan the Alexandrian series immediately overlies the Maquoketa. Lane[17] attempts to differentiate the Maquoketa on a lithologic basis and so correlates these strata with strata of Richmond age in Wisconsin, New York,Ohio,Indiana and on Manitoulin Island. Later writers have shown that the Maquoketa of Iowa,Illinois and Wisconsin,while a time equivalent of the upper Richmond is not to be considered a westward continuation of the latter strata,but belongs to a different geological province from the Richmond strata of Ohio and Indiana.

The following more typical logs indicate the thickness and depth below the surface at which the Maquoketa is encountered:

Record of the John Wagner well. Hole No.2.

Location: SW 1/4,NW 1/4,sec.8,T 39 N,R 21 W. Elevation about 650 feet. Three to four miles northeast of Stonington,Mich., Drillers: Gunter of Escanaba and Chris Skaug of Stonington.

		Thickness, feet.	Depth, feet.
	Surficial material		
8.	Sand and gravel.....	8	8
	Maquoketa formation		
7.	Limestone,fossiliferous.....	32	40
6.	Shale and limestone,in alternating layers....	200	240
5.	Shale,bituminous.....	250	490
	Platteville-Galena,St.Peter,Prairie du Chien,Potsdam.		
4.	Limestone,sandstone and blue shale.....	490	980
3.	Hematite,two veins 2 and 7 inches thick,interbedded in sandstone.....	1	981

2.	Sandstone.....	29	1010
	Huronian quartzite		
1.	Quartzite,white,hard,with included pebbles...	68	1078

Log of well 2 miles east of Ensign,on south side of railroad.*

3.	Alluvium.....	4	4
	Maquoketa formation		
2.	Shale,black.....	485	489
	Platteville-galena limestone		
1.	Limestone,white,sandy.....	1	490

Log of well at State Insane Asylum at Newberry.

(Elevation 865 feet.)

3.	Alluvium,sand,gravel.....	320	320
	Maquoketa formation		
2.	Limestone.....	67	387
1.	Shale.....	70	457

In a limestone quarry 12 miles southeast of Newberry,sec.6, T 44 N,R 8 W,elevation 900 feet,two wells strike limestone at a depth of 100 feet.

Exposures of the Maquoketa beds in the western region were seen along the banks of Wisner Creek,two miles west of Alton,where bluffs 45 feet in height show the following section:

Section of Strata exposed on Wisner Creek,sec.10,T 40 N,R 21 W.

(Elev.at top of bluff in road 648 feet.)

		Thickness, feet.	in.
9.	Limestone,gray,hard,non-fossiliferous.....	8	

* This record was given by J.Scheska,of Rapid River,from memory and therefore its accuracy is not vouched for.

8.	Limestone,gray,very soft,cherty in places, largely a mass of shells of Rafinesquina alternata.....	11	
7.	Talus covered interval.....	18	
6.	Limestone,gray,hard,compact,with few fossils.	2	
5.	Shale,brownish-gray,soft;weathers easily to a fine powder,largely composed of bryozoa.	1	
4.	Limestone,crinoidal,composed of finely comminuted fragments of brachiopods, gastropods,crinoids,etc.....		2
3.	Limestone,gray,hard,conchoidal fracture, containing few fossils.....	1	6
2.	Shale,brown to gray,soft,non-calcareous;with many bryozoa.....	1	
1.	Limestone,gray,hard,with thin layer of crinoidal limestone separating it from the overlying shale& This stratum forms the bed of the creek.....	2	
		43	6

In a railroad cut one mile west of Ensign a low outcrop of Maquoketa shales and limestones occurs on both sides of the right- of -way for a distance of one thousand feet,but due to the cover of alluvium it cannot be traced far either north or south of this place. It marks in all probability the eastern border of the pre-glacial Maquoketa escarpment whose lower benches are now covered by the series of high sand bluffs seen just east of the Whitefish River,and which continue to the north for a distance of several miles. The following section shows the character of the strata exposed in the railroad cut last mentioned:

Section exposed in M.St.P.& S.Ste.Marie R.R. cut,one mile east of Ensign.

(Elev.669 feet.)

		Thickness, ft.	in.
7.	Alluvium,and material from cut.....	4	
6.	Limestone,gray,brittle,with many calcite crystals scattered thruout,bryozoa numerous.....		10
5.	Shale,black;with few fossils.....		2
4.	Limestone,gray,with dark streaks thruout and containing many bryozoa.....		6
3.	Shale,black,soft,when dry is light gray,with few fossils.....	1	6
2.	Limestone,gray,very dense,with calcite druses at top and many bryozoa.....	1	
1.	Shale,black,soft,similar to No.3;with few fossils.....	3	
		11	

An exposure farther west,on the east side of Little Bay de Noc,presents very typically the character of the Maquoketa strata, as shown in the following section:

Section of Strata exposed in the SE 1/4 sec.26,T 39 N,R 22 W.

		Thickness, ft.	in.
6.	Limestone,bluish to ashen,massive,shaly, very fossiliferous.....	20	
5.	Shale,blue,indurated.....	2	6
4.	Limestone,very shaly,fossiliferous,with regular patches of shale intermixed.....	2	6
3.	Shale,blue,greenish on fresh surfaces.....	5	6

2.	Limestone,bluish,very shaly,fossiliferous....	1	3
1.	Shale,greenish on fresh surfaces,blue on weathered surfaces.....	6	6
		38	3

Altho no exposures have been noted between the Little Bay de Noc region and the Manistique Lakes,the following log of a drilling shaws the presence of the Maquoketa in this area,parallel with and to the north of the area of outcrop of Hendricks dolomite.

Record of well of Wm.Mueller Lumber Co.,at Blaney.

		Thickness, feet.	Depth, feet.
5.	Clay,loam and sand.....	15	15
4.	Quicksand.....	26	41
3.	Gravel	4	45
2.	Bowlder clay,blue.....	68	113
1.	Shale.....	101	214

This record is especially interesting because the well is immediately north of the Hendricks dolomite exposure near Blaney quarry and shows that the contact between the Maquoketa and the Alexandrian occurs somewhere in the few miles between these two localities.

The next exposure to the east was seen on the north side of North Manistique Lake where massive,dense,white,unfossiliferous dolomite outcrops on the farm of Wm.Bowler,NW 1/4,SW 1/2,sec.20, T 45 N,R 11 W,covering about an acre. A record of a well on this farm follows:

Record of well of Wm.Bowler;elev.735 feet.

		Thickness, feet.	Depth, feet.
5.	Alluvium and sand.....	20	20
4.	Dolomite,white,much fissured.....	20	40
3.	Limestone,white,very soft.....	2	42
2.	Gravel(?),white.....	5	47
1.	Limestone,white.....	13	60

Immediately south of this farm,on the west side of the road going south to the lake,scattered outcrops of the same dolomite as No.4 above,were seen. The presence of non-glaciated slabs of this dolomite testifies to the presence of the Maquoketa over a considerable area in this vicinity. The following records show that it is but slightly buried:

North Manistique Lake.

School-house well,sec.29,T 45 N,R 12 W;depth 96 feet, struck limestone at 40 feet.

Jerry Holland well.

E.side of sec.30,T 45 N,R 12 W;depth 85 feet,struck limestone at 18 feet.

Chas.McKinnon well.

Sec.29;across road and 35 feet above last well,depth 86 feet,struck limestone at 40 feet.

John Richards well.

South part of sec.21,T 45 N,R 12 W;depth 76 feet,struck limestone at 75 feet.

This same bed of dolomite is exposed on the north side of North Manistique Lake,half a mile south of the exposure on the Bowler farm,where the ledges slope gently southward and extend some

distance into the lake. Outcrops farther east,on the road between Helmer and Round Lake,show the rock to be of essentially the same character as in the outcrops above described,but the strata were unfossiliferous. Outcrops and unglaciated limestone slabs west of Curtis contained Maquoketa fossils. It is these rocks to which Rominger probably referred in his descriptions of the lower Silurian strata on the shores of North Manistique Lake.

TABLE IV.

The following fossils were collected from the Maquoketa group in Northern Michigan:

Locality 3C1. West of Curtis on north and south sides of railroad.

Dalmanella testudinaria (Dalman).

Plectambonites sericeus (Sowerby).

Zygospira modesta Hall.

cf.Isotelus sp.

cf.Ptychopyge sp.

Locality 2C1. In railroad cut one mile west of Ensign.

Dalmanella testudinaria (Dalman).

cf.Schizambon?lockei W.& S.

cf.Saffordia sp.

Proetus sp.

Isotelus sp.

Locality 1C1. From bluff on Geo.Demitt farm;sec.10,T 40 N,R 21 W, 1 mile west of Alton.

Dalmanella testudinaria (Dalman).

Lingula cf.cobourgensis Billings.

Lingula sp.

Rafinesquina alternata (Emmons).

Rafinesquina alternata cf.var.fracta (Meek).

Strophomena planumbona (Hall).

Strophomena cf.planumbona (Hall).

Trematis millepunctatus Hall.

Byssonychia radiata Hall.

Clidophorus neglectus Hall.

Pterinea (Caritodens) demissa (Conrad).

Liospira vitruvia (Billings).

Lophospira cf.tropidophora Meek.

Lophospira tropidophora Meek.

Lophospira spironema U.& S.

Lophospira sp. A.

Lophospira sp. B.

Trilobite segments.

TABLE VII.

Comparative Table of Fossils.

Column 1,from the Maquoketa of Michigan as described in this paper.

Column 2,from the Maquoketa of Wisconsin;listed by Dr.T.E.Savage.

	1.	2.
Ceramporella ohioensis		X
Ceramporella granulosa		X
Crepipora hemispherica		X
Crepipora simulatus		X
Heterotrypa subramosa		X
Heterotrypa singularis		X
Constellaria polystomella		X
Eridotrypa granulata		X
Lioclemella solidissima		X
Hallopora crenulata		X
Hallopora subnodosa		X
Batostoma varium		X
Monotrypa nodosa		X
Fenestella granulosa		X
Dicranopora fragilis		X
Lingula iowensis		X
Rafinesquina alternata	X	X
Rafinesquina kingi		X
Rafinesquina alternata cf.fracta	X	
Leptaena unicostata		X
Plectambonites sericeus	X	X

	1.	2.
Strophomena neglecta		X
Strophomena planumbona	X	X
Strophomena wisconsinensis		X
Dalmanella testudinaria	X	X
Dinorthis subquadrata		X
Hebertella occidentalis		X
Hebertella insculpta		X
Plectorthis whitfieldi		X
Rhynchotrema anticostiensis		X
Rhynchotrema capax		X
Rhynchotrema inaequivalvis		X
Rhynchotrema neenah		X
Rhynchotrema perlamellosa		X
Zygospira modesta	X	X
Lingula cf.cobourgensis	X	
Lingula sp.	X	
Trematis millepunctatus	X	
cf.Schizambon?lockei	X	
Hormotoma gracilis	X	X
Cyclonema bilix		X
Liospira vitruvia	X	
Lophospira cf.tropidophora	X	
Lophospira tropidophora	X	
Lophospira spiromema	X	
Lophospira sp.	X	
Clidophorus neglectus	X	

	1.	2.
Pterinea (Caritodens) demissa	X	X
Byssonychia intermedia	X	X
Byssonychia radiata	X	X
cf.Saffordia sp.	X	
Isotelus cf.maximus	X	X
Calymene senaria		X
cf.Ptychopyge sp.	X	
Proetus sp.	X	

Note:- Bryozoa collected from the Maquoketa of Michigan are not included in this list.

THE SILURIAN SYSTEM.

Smith has recently divided the Silurian rocks in Michigan into the following formations:-

Niagaran series.
5. Monroe series.
4. Engadine dolomite.
3. Manistique series.
2. Fiborn limestone.
1. Hendricks series.

Tho this classification was made entirely upon a lithologic basis it has been found to be in part consistent with that of later studies based on the stratigraphy of the rocks.

That Smith erred in his grasp of the significance of the stratigraphic features involved is shown by his application of the term "series" to a division of a series,as the Manistique series of the Niagaran series of the Silurian system. In view of this,and as a result of the writer's field and office studies,the following divisions of the Silurian system in this area are proposed;the reasons for making these divisions together with their stratigraphic relations will be given on a later page.

System.	Series.	Stage.
Silurian	Cayugan	Monroe limestone.
	Niagaran	Engadine dolomite.
		Manistique dolomite.
	Alexandrian	Fiborn limestone.
		Hendricks dolomite.

In this paper the above nomenclature will be used.

Detailed Stratigraphy of the Alexandrian Series.

In the northern peninsula of Michigan the Alexandrian series is represented by two formations, the lower is the Hendricks dolomite and the upper the Fiborn limestone. These formations are apparently conformable as shown in the various detailed sections herein given. The Hendricks is doubtless unconformable upon the Maquoketa beds, while the Fiborn is probably separated from overlying Niagaran strata by a sedimentary break. From the record of a well at the Union Carbide Co's., quarry at Hendricks, it is shown that there are at least 145 feet of Hendricks dolomite below the Fiborn limestone, and from records of wells farther east the depth to rock that has been called Ordovician is 225 feet. From the relations shown in the sections of the Dickinson, Seaman and Marble Head quarries on Drummond Island, the thickness of the Hendricks is seen to vary from 145 to 200 feet. These thicknesses are consistent with the statement of Savage[22] that in the vicinity of Mayville, Wis., there is 140 feet of Mayville limestone (Alexandrian) below the base of the Virgiana zone. The Following is a typical section of the Mayville limestone:

Section of Mayville limestone exposed in a quarry 3 miles south of Mayville, Wis.

		Thickness, feet.
5.	Dolomite, yellowish gray, vesicular, in layers 2 to 6 feet thick containing numerous casts and molds of shells of *Virgiana barrandei mayvillensis*.....	21

(22), Savage, T.E., Geol. Soc. of Am., Bul. 27, 1916, p. 308.

4.	Dolomite,yellowish gray,hard,with many irregular cavities and a few casts of shells of Virgiana barrandei mayvillensis.....	10
3.	Dolomite,hard,massive,crystalline,in layers 4 to 6 feet thick.....	33
2.	Dolomite,yellowish gray,fine grained,in layers 4 to 6 inches thick.....	32
1.	Dolomite,hard,crystalline,in rather thick layers having numerous irregular cavities.....	22
		118

The Fiborn limestone ranges in thickness from 3 feet(?) on Drummond Island,15 feet at Fiborn quarry,18 feet at Hendricks quarry, to 27 feet at Blaney quarry. A steadily increasing thickness to the west.

The Hendricks Dolomite.

The areal extent of the Hendricks dolomite member can only be conjectured since there are but three small exposures known and they are confined to the eastern part of the region. In the district extending from St.Marys River on the east to Big Bay de Noc on the west this formation probably underlies the surficial materials thruout a similar arcuate belt as do the other Paleozoic formations. It occurs immediately north of the Fiborn limestone area and south of the belt of Maquoketa shales and limestones. The most easterly known outcrop of this dolomite is on the west side of Lime Island, where 6 feet of buff,sandy dolomite is exposed in an abandoned quarry. These strata contain abundant casts and molds of shells of Virgiana barrandei mayvillensis,the most typical fossil of the ~~lower~~ Alexandrian,or Mayville limestone,in Wisconsin. Farther west, in a test pit and also in a crusher pit at Hendricks quarry,a thick-

ness of 25 feet is exposed. These layers,as noted in the descriptions of strata Nos.1 to 21 of the Hendricks quarry section,are essentially dolomitic or magnesian limestone rocks*. They contain the fossils

Atrypa putilla
Homeospira subcircularis
Spirifer cf.eudora
Orthis flabellites.

These species alone clearly indicate the Edgewood age of the Hendricks formation. Immediately north of the quarry at McLeod's Bluff,the horizon of the Hendricks dolomite is covered by a heavy talus over the lower part of the bluff. In the latter there occur numerous cherty,unglaciated limestone fragments containing casts and molds of shells of Virgiana barrandei mayvillensis,which fact indicates that the virgiana zone is present and near the surface.

The next westerly exposure of these rocks occurs south of South Manistique Lake,where a low ridge of Hendricks dolomite cuts across secs.4,5 and 6,T 43 N,R 11 W,at an elevation of 740 to 750 feet,and declines rapidly toward the north. The outcrop,only a few square feet in area,is in a densely wooded and swampy district where little can be gained as to the relations of this rock to the associated strata. The following well record shows the depth to bed rock in this region:

* See Table IIII,p.82.

Fig.5

Hendricks dolomite in Test Pit;

Hendricks quarry.

Fig.6

Test Pit in Hendricks dolomite,with Fiborn limestone in distance;

Hendricks quarry.

Fig.7

Fiborn limestone at Hendricks quarry.

Record of the Frank Mitchell well;NE 1/4 sec.20,T 44 N,R 11 W.

		Thickness, feet.	Depth, feet.
8.	Alluvium.....	4	4
7.	Gravel.....	1	5
6.	Clay,blue,stiff.....	1	6
5.	Quicksand.....	10	16
4.	Gravel.....	20	36
3.	Clay,blue.....	1	37
2.	Quicksand.....	20	57
1.	Limestone,white.....	5	62

The most westerly exposure of this formation occurs at Blaney quarry,two miles north of Blaney Junction on the Minneapolis, St.Paul & Ste.Marie railroad,where a thickness of very white,crystalline dolomite is seen below the Fiborn limestone,separated from it by what is interpreted to be an unconformity. About three-fourths of a mile north of the quarry is an outcrop of Hendricks dolomite which covers nearly two hundred square yards. From this last exposure good Edgewood fossils as Atrypa putilla and Spirifer cf.eudora were obtained. On Garden Peninsula,just north of Van's Harbor, finely preserved casts of shells of both Virgiana barrandei mayvillensis and V.barrandei major were collected from a pile of bowlders, mainly drift. In this last area the Manistique dolomite immediately underlies the glacial drift.

The major portion of the region is so nearly covered by dense woods or by muskegs,both of which are almost impassable,that no exposure of the contact of the Hendricks and Maquoketa beds has yet

been found. These two formations are doubtless separated by an unconformity as are the Mayville beds and Maquoketa in Wisconsin.

A detailed section of the rocks in Hendricks quarry follows:

Section of strata exposed in Hendricks quarry.

		Thickness, feet.	inches
	Fiborn limestone		
24.	Dolomite, gray, thin bedded, vesicular.....	6	
23.	Dolomite, gray, dense, badly disintegrated, in places cherty.....	4	
22.	Limestone, brownish gray, dense, fine grained, high calcium content, fracture sharply conchoidal, earthy in appearance, disseminated druses and crystals of calcite, numerous species of Leperditia and Favosites forbesi var. abundant. (Analysis No.401)*.....	18	
	Hendricks dolomite		
21.	Limestone, white, fissils, high calcium content, fossiliferous, with some black streaks, flakes off in laminae 1/4 to 2 inches thick. (Analysis No.403 and No.404)....	8	
20.	Limestone, lithographic, similar to stratum No.22. (Analysis No.405).....	1	
19.	Limestone, grayish white, fissile, thin bedded, stylolythes prominent. (Analysis No.406)	1	4
18.	Limestone, yellowish white, hard, massive. (Analysis No.407).....	2	8
17.	Dolomite, yellowish brown, fossiliferous, crystalline, massive. (Analysis No.408).	5	9
16.	Limestone, yellowish brown, soft, high calcium content. (Analysis No.409).....	1	
	Floor of Test Pit.		
15.	Limestone, white, high calcium content, with black streaks 1/4 to 2 inches apart, in upper 1 foot there is a tendency to part along bedding.....	8	10

* See Table IV.

14.	Limestone,lithographic,similar to stratum No.22.....	1	
13.	Dolomite,white,dense,with black streaks.....	2	8
12.	Dolomite,whiteish,dense,with no streaks.....	1	9
11.	Limestone,yellowish brown,high calcium content,above grading to a gray at base where it becomes more massive,contains numerous small solution cavities.....	6	
10.	Limestone,three layers respectively 9 inches, 13 inches and 15 inches thick,brownish gray,fine grained,lacking the usual calcite druses. These layers are separated by thin clay bands.....	3	
9.	Limestone,lithographic at base,passing upward into a cherty clay agglomerate.....	1	6
8.	Clay band.....		3
7.	Limestone,grayish white,magnesian,crystalline		7
6.	Clay band.....		3
5.	Limestone,graysih white.....	2	
4.	Dolomite,white,highly crystalline.....		9
3.	Limestone,white,crystalline.....	1	6
2.	Limestone,grayish white.....	1	
1.	Dolomite,gray to white,crystalline,massive, breaking with a conchoidal fracture, exhibiting no bedding. Floor of Crusher pit.....	2	
		81	0

In Wisconsin, Virgiana barrandei mayvillensis is associated with Coelospira convexa,and a like association of these fossils occurs in the Bescie River section of Anticosti Island. Savage[22] considers that these horizons may possible be correlated with the Manitoulin member of the lower Cataract formation of Manitoulin

(22),Savage,T.E.,Bul.Geol.Soc.Am.,v.27,p.313. 1916.

Island. He adds,however,that it is more probable that the Cataract corresponds to a somewhat subsequent time. To quote him "the Manitoulin member not only contains Coelospira planoconvexa in considerable numbers,but also Rhinopora verrucosa and a number of other species characteristic of horizons near the middle of the Sexton Creek limestone,with which formation the Manitoulin member is probably the equivalent in time". No fossils showing the slightest affinity to Virgiana have been described from the Cataract. Williams[28] gives the following section for the Silurian of Manitoulin Island:

Section of Silurian Strata exposed on Manitoulin Island.

		Thickness, feet.
3.	Lockport formation,dolomite,thick and thin bedded.....	240
2.	Shale,red,clayey,with green discolorations near top.....	27-66
1.	Cataract formation,dolomite,massive midway, thin bedded and clayey at base, thin bedded at top.....	50-60

The above section is representative for the eastern portion of Manitoulin Island,in the vicinity of Little Current and Manitowaning,but in view of the relations shown by the section exposed at Dickinsons quarry on the eastern side of Drummond Island where members Nos.1 to 4 are certainly of Alexandrian age as are members Nos.1 to 5 at the Marble Head quarry,which are 28 feet thick,it cannot hold for the western side of the island. False Detour

(28),Williams,M.Y.,Canada Geol.Survey,Guide Book No.5,p.91. 1913.

Channel separating Drummond from Cockburn Island,the latter immediately west of Manitoulin,is but a mile wide,so is safe to assume that when the stratigraphy of Manitoulin Island is carefully studied the thinning eastward margin of the Alexandrian will be found;the horizon farther east being followed by the younger Cataract formation.

TABLE V.

The following fossils have been collected from the Hendricks dolomite:

Locality 3H2. Hendricks quarry, stratum 17.

Zaphrentis sp.

Camarotoechia?winiskensis Whiteaves.

Locality 3H3. Hendricks quarry, stratum 19.

G Atrypa putilla Hall.

Camarotoechia?winiskensis Whiteaves.

Cyclonema sp.

Illaenus sp.

Locality 3H1. Hendricks quarry, stratum 20.

Atrypa delicatula

G Camarotoechia?winiskensis Whiteaves.

Spirifer cf.eudora (Hall).

Spirifer cf.sulcatus Hisinger.

Illaenus sp.

Locality 3H4. Sec.5, T 43 N, R 11 W.

G Spirifer cf.eudora (Hall).

Favosites forbesi var.

Locality 4H1. Three-quarters mile north of Blaney quarry.

Atrypa reticularis Linnaeas.

G Homeospira subcircularis Savage.

Atrypa sp.A.

Atrypa sp.B.

G Spirifer cf.eudora (Hall).

Camarotoechia?winiskensis Whiteaves.

Favosites forbesi var.

Leperditia ohioensis.

Leperditia sp.

Locality 5H1. Quarry, west side of Lime Island.

G Virgiana barrandei mayvillensis Savage.

Locality 6H1. Drift, north of Van's Harbor.

G Virgiana barrandei mayvillensis Savage.

G Virgiana barrandei major Savage.

The Fiborn Limestone.

At all places where the Hendricks dolomite has been observed in the Northern Peninsula of Michigan,it is immediately overlain by a light gray to grayish brown limestone composed of an almost impalpable powder,with individual rhombs and drusy calcite segregations or replacements scattered thruout,and having a sharply conchoidal tho earthy fracture. It is generally massive,tho locally it is strongly laminated. Joint systems are irregular and poorly developed. Where exposed at the surface it has been calcined white by numerous forest fires. Thruout its extent it is distinctly a high calcium,lithographic limestone with 94 to 99% $CaCO_3$.*

To this limestone Smith [5] provisionaly applied the name "Fiborn limestone",from the characteristic exposure in Fiborn quarry. He states that the formation was distinguished on a lithologic basis, and thinks that "further field work and faunistic studies may show that the Fiborn limestone should be included in the Hendricks series". Studies of the writer show that the Fiborn is to be regarded as the upper member of the Alexandrian series,younger than the Hendricks dolomite,and about the same age as the upper Mayville limestone and lower Byron beds of Wisconsin.

The Fiborn limestone is exposed over an arcuate belt from a point four miles north of Whitedale (near the center of the south line of sec.2,T 42 N,R 14 W),east to Gould City,and northeast to McLeod's Bluff,near Hendricks quarry,thence southeast thru Fiborn quarry to within two or three miles of Trout Lake where it is lost beneath the drift. It next appears to the east on Lime Island,in

*See Table IV for detailed analyses.

St.Marys River,where fragments of but slightly weathered Fiborn limestone near the abandoned quarry on the west side of the island,and an exposure of six feet of buff dolomite containing many casts and molds of shells of Virgiana barrandei mayvillensis,indicate that this horizon is present.

The thickness of the Fiborn limestone in the eastern portion of the area is variable,but in Blaney quarry at the western end of the belt of exposures,it has a thickness of 26 feet. The following well record will show the succession of strata down to,and including, what is interpreted to be Fiborn:

Record of well at cor.Garden Ave.,and Potter St.,Manistique,Mich.[20]

(Elevation 595 feet)

		Thickness, feet.	Depth, feet.
17.	Sand.....	2	2
	Manistique dolomite.		
16.	Dolomite,light buff,massive.....	2	4
15.	Limestone,light,dolomitic.....	11	15
14.	Dolomite,bluish white.....	9	24
13.	Limestone,brownish,crystalline,dolomitic.....	16	40
12.	Limestone,light blue,dolomitic.....	12	52
11.	Limestone,buff,crystalline,cherty.....	13	65
10.	Limestone,white.....	7	72
9.	Limestone,buff,crystalline,dolomitic.....	10	82
8.	Limestone,white.....	27	109
7.	Dolomite,gray,mottled.....	16	125
6.	Dolomite,buff.....	13	138

(20),Smith,R.A.,Mich.Geol.Surv.,pub.14,ser.11,p.241;1912.

5.	Dolomite,yellow.....	22	160
4.	Limestone,yellow.....	12	172
3.	Dolomite,yellow.....	30	202
	Fiborn limestone		
2.	Dolomite,lithographic,white,thin banded.....	10	212
	Hendricks dolomite		
1.	Limestone,white.....	15	227

Smith thinks stratum No.8 may be the Fiborn limestone,and that No.3 may be the top of the Byron beds ofWisconsin or the base of the Coralline of Rominger. That this is improbable is shown by the fact that with the observed dips of 40 to 50 feet per mile,exposures should occur within five miles north of the above location or just beyond the Niagaran cuesta,while the stratum Smith interprets as Fiborn should come to the surface three miles south of the cuesta. If stratum No.2 be considered as Fiborn it is seen that with the known dip it would come to the surface where it should be expected, that is,at the base of the cuesta. If this member No.2 represents the Fiborn limestone,its thickness appears to be diminishing toward the south,a fact in entire accord with deep well records from lower Michigan.

Smith[5] notes that "small exposures of Fiborn limestone occur about four miles northeast of Trout Lake in sec.24,T 44 N,R 7 W", where it is considerably thinner than in the exposure at Fiborn quarry as is shown by the following well records:

(5),Smith,R.A.,Mich.Geol.Surv.,pub.21,ser.13,1915,p.207.

Record of well one mile N.E.of Trout Lake,Mich.*

		Thickness, feet.	Depth, feet.
4.	Alluvium.....	5	5
	Fiborn limestone		
3.	Limestone,gray.....	20	25
	Hendricks dolomite		
2.	Limestone,reddish,gray streaks.....	40	65
1.	Limestone,gray.....	160	225

Record of John England well at Trout Lake,Mich.*

5.	Alluvium.....	6	6
	Fiborn limestone		
4.	Limestone,grayish white.....	12	18
	Hendricks dolomite,Maquoketa beds		
3.	Limestone,gray.....	328	346
2.	Limestone,gray,sandy.....	75	421
1.	Shale,black.....	95	516

The following sections of strata exposed at Fiborn,Hendricks#, Blaney,and Boyle's quarries,respectively,show in more or less detail the general lithographic character and stratigraphic relations of the Fiborn limestone.

Section of Fiborn limestone in Fiborn Quarry.[7]

		Thickness, feet.
5.	Limestone,with Orthoceras,a gastropod, Favositoid and Stromatoporoid corals....	3
4.	Limestone,greenish,sandy,with greenish tubes anastomosing,some Stromatoporoids.....	1

* Data furnished by J.Scheska from memory and hence not vouched for.

See Hendricks quarry section,p.60.

3. Limestone,brown and light colored,mottled, with Stromatoporoid masses probably Clathyrodictyon vesiculosum..... 4

2. Limestone,very massive..... 6

Hendricks dolomite

1. Limestone,calcilutytic,drusy in places,a species of Leperditia and styloitic structures occur in the lower part which is more porcelanic than that above..... 9

23

It is probable that stratum No.1 of the above section is the same as the top stratum of the test pit at Hendricks quarry.

Section on northeast side of Blaney Quarry.

		Thickness, Feet.	Inches.
	Fiborn limestone		
4.	Limestone,gray,lithographic,vesicular, with many Stromatoporoid and Favositoid corals.....	1	6
3.	Limestone,gray,very fine grained,with much calcite scattered thru it, lithographic.....	24	6
2.	Limestone,gray,lithographic,in thin laminae alternating with lenticular calcite druses.....	2	
	Disconformity?		
	Hendricks dolomite		
1.	Dolomite,white,highly crystalline.....	1	3
		28	5

Section of strata exposed in the B.F.Boyle Quarry.

(Elevation 649 feet)

		Thickness, Feet.	Inches.
3.	Limestone,light blue,upper part decomposed,		

(Note) See TableIV for analyses.

	showing traces of Fe,and of dolomitization,Stromatoporoids abundant in the upper zone.....	6	2
2.	Clay,residual?,buff,sandy.....		2
1.	Limestone,blue,hard,with angular fracture....	5	4
		11	8

At all exposures observed,with possibly one exception,the Fiborn limestone was apparently in entire conformity with the underlying Hendricks dolomite. However,the change in lithology is everywhere sharp from the buff,semi-crystalline Hendricks dolomite to the dense,massive,lithographic limestone of the Fiborn beds. This is very clearly seen from the Hendricks and Fiborn quarry sections. The exception is at Blaney quarry where there is evidence of a break in sedimentation between these formations. At this place the lower 14 inches of the Fiborn consists of small,lenticular,drusy,calcite segregations which serve as laminae in separating the thin lithographic lamina. Below the former,calcitic,stratum is a crystalline dolomite,white,and compact,the surface of which appears to be ripple-marked over the few square feet of area exposed.

As will be noted in the section given for Fiborn quarry,the upper two beds are more or less magnesian,with abundant corals. The same relations obtain to the west as may be seen from exposures along the south line of secs.4,5 and 8,T 43 N,R 12 W;elsewhere the Fiborn as exposed is a normal lithographic limestone. The altitude of the most westerly exposure,sec.4 of the above township,is 671 feet;the elevation of the top of rock at Boyles quarry is 649 feet. At the former place the rocks contain Favosites forbesi var.,while at the latter they are unfossiliferous and of a wholly different lithologic

Fig.8

Fiborn-Hendricks contact;Blaney Quarry.

Hammer point is at disconformity (?).

Fig.9

Fiborn limestone at Blaney quarry.

composition,and contrary to the idea of Smith[5],represent not the Fiborn,but the Manistique dolomite. What relation this dolomite holds to the Fiborn limestone the writer was unable to determine,thru lack of time for the field study. However,it is certain that it has been eroded irregularly from the underlying lithographic limestone, and that it contains typical Fiborn fossils.

A.Winchell[2]thot that the lower 32 feet of limestone at the eastern extremity of Drummond Island corresponds to the upper portion of the Clinton of New York. The following section of strata in Dickinsons quarry shows the relations of these rocks on Drummond Island:

Section of bluff in Dickinsons Quarry,near the east end of Drummond Island[4].

		Thickness, feet.
16.	Limestone,light gray,hard crystalline,weathers rough,abounds with shells of Pentamerus oblongus;the highest ledge.....	6
15.	Limestone,in thin,much broken layers.....	8
14.	Limestone,rough,crystalline,geodiferous, abounds with Pentamerus oblongus and corals.....	26
13.	Concealed slope,which,allowing for dip gives.	19
12.	Limestone,gray,crystalline,hard,forms upper ledge south of quarry.....	7
11.	Limestone,areno-calcareous,weathers rough, abounds in fossils. Forms the upper ledge south of quarry.....	5
10.	Limestone,argillo-calcareous below,resembles No.8;above areno-calcareous,resembles No.11;weathers unequally;some Cyathophylloid corals in the upper part.....	2

9. Limestone,dark gray,crystalline. Interpreted as the base of the Manistique dolomite.. 1/2

8. Limestone,white,very fine-grained,weathers white in the upper part,cherty and mottled in the lower part. Interpreted as Fiborn limestone..... 3

7. Limestone,areno-calcareous,some cherty mottlings,the lower half very hard,the upper softer and striped with brown..... 4

6. Limestone,arenaceous,with hard interlaminated layers,becomes vesicular downward..... 2

5. Limestone,dark gray,very hard,with small geodes,beautifully ripple-marked at top. 2

4. Limestone arenaceous,thinly laminated,dark colored,traces of fucoids or of branching corals on the upper surface..... 2

3. Limestone,brown,very hard..... 1

2. Limestone,dark,areno-calcareous,with alumina disseminated thru it in wavy streaks.... 2

1. Limestone,argillo-calcareous,ashen colored, very fine grained,thick bedded - a single stratum being 4 1/2 feet thick. Contains shells of species of Leperditia,Murchisonia,and an Aviculoid. Distance to water..... 7 1/2

98

The strata exposed on Drummond Island have been described by Winchell and Rominger. They are essentially shaly limestones, fine grained,white to ashen in color and evenly bedded,occurring in layers 2 to 3 feet thick and having a gentle dip towards the south. Some of the layers are lithographic and portions are so homogeneous as to seem to be composed of earthy,impalpable powder. Rocks lower in the group outcrop successively along the shore of the Island from Dickinsons quarry to Pirate Harbor,a distance of three miles along the strike of the formation. They also reappear on the northwest side of the Island at Brown's and Ludlow Seaman's quarries.

The following section represents a westward continuation of the strata exposed in Dickinsons quarry:

Section of rocks in the Ludlow Seaman Quarry on Drummond Island.[5]

		Thickness, feet.
12.	Surface material.....	3
11.	Limestone,magnesian,light to grayish buff, fossiliferous,numerous Pentamerus oblongus. About 4 feet of rock exposed, the basal portion of the bed concealed by talus.....	8
10.	Limestone,similar to No.11,composed largely of casts of shells of a species of Pentamerus. Thickness exposed about 3 feet,the rest of the interval is talus covered.....	15
9.	Limestone,like No.10 but with fewer fossils.	15
8.	Dolomite,buff,very dense,thin bedded,conchoidal fracture,resembles novaculite. Only upper 6 feet exposed,top of quarry.	25
7.	Dolomite,buff to gray,hard,massive,crystalline.....	3
6.	Dolomite,light gray to buff,massive,crystalline,separated from No.5 by a parting of very thin bedded dolomite.....	3
5.	Dolomite,light buff,hard,massive,crystalline, similar to No.6.....	4
4.	Dolomite,buff,hard,densely crystalline,conchoidal fracture.....	8
3.	Dolomite,dark buff,crystalline,with a drusy, fossiliferous zone near the middle.....	3
2.	Dolomite,light gray,often buff,hard,finely crystalline,and finely banded,with prominent bedding planes.....	7
1.	Dolomite,hard,blue,fine grained,weathers to a pronounced blue color.....	2
		96

A section similar to the last is exposed in a large quarry on Quarry Point,about one mile farther west. The massive,crystalline beds corresponding to Nos.1 to 7 are dolomite,as shown by analysis No.240,Table IV.

The rocks in the above section contain few fossils,among which are species of Avicula,Murchisonia and Cytherina(Leperditia). (As previously noted,Hall referred to similar fossils from the lower part of the Burnt Bluff section). Shells of Leperditia are common at all outcrops and thruout the entire vertical thickness of this formation. On the basis of lithographic texture,the characteristic Leperditia fauna of the Fiborn,and the fact that the exposure lies on the northern flank of the belt of arcuate outcrop of the Fiborn on the mainland,it is safe to assume that these strata represent a continuation of the Fiborn limestone from Lime Island.

After describing the rocks of the Manistique dolomite member of the Niagaran series exposed at Marble Head quarry on the northeast side of Drummond Island,Rominger[3]remarks that immediately below them are three feet of ash-colored,fine grained limestones,in beds from 4 to 8 inches thick,some of which are full of fissure-like cavites penetrating them in all directions,which are the empty spaces once occupied by tabular spar crystals. Underneath these occur 8 feet of yellowish gray,regularly bedded limestones,of dull,earthy,uneven fracture. They inclose drusy cavities filled with calc-spar,and contain the casts of shells of Avicula cf.rhomboidea,Leperditia,and a tuberose form of Favosites forbesi var. The next succeeding rock is a dark,irregularly bedded,bituminous limestone,5 feet thick,of heterogeneous,nodular structure. It contains several poorly preser-

ved fossils including,Favosites,Leperditia,and Rhynconella in apparently the same species as were found in the overlying beds. At the base of the section there occurs a thickness of 10 feet of light colored,porous limestones,parting in thin slabs,with an uneven conchoidal fracture. The lowest layers are dark and full of a branching, fucoid-like elevation,probably a species of Clathyrodictyon;the only distinct fossil recognized in them being a species of Leperditia. It is thought that the three foot bed noted above is the eastern extension of the Fiborn limestone greatly diminished in thickness. This correlation is based on the lithologic character,the high calcium content,the Leperditia fauna,and the presence of Favosites cf.forbesi var. The latter it will be noted,on a following page,is a guide fossil of the Alexandrian series in Michigan. An additional fact of significance is that the exposures in this quarry lie within the limits of the general trend of arcuate outcrop of the Fiborn,and is in the line of continuation of exposures on Lime Island and at Dickinsons quarry. Following is a section exposed at Marble Head quarry;strata Nos.6 to 13 being interpreted as of Niagaran age,Nos. 4 and 5 of Fiborn age,and Nos.1 to 3 of Hendricks age.

Section of Strata exposed at Marble Head Quarry,on Drummond Island, one fourth mile from Pirate Harbor[5]

		Thickness, feet.
13.	Limestone,light colored,magnesian,irregularly bedded.....	25
12.	Dolomite,light cream colored,massive,coarsely crystalline,obscurely bedded,filled with casts of Pentamerus oblongus.....	15
11.	Dolimite,fine grained,thinly and irregularly bedded.....	4

10.	Drift covered interval.....	4
9.	Limestone,dark gray,highly crystalline,with siliceous veins,containing many fossils. Top of quarry.....	12
8.	Limestone,dark gray,dull,laminated,becoming non-fossiliferous toward bottom.....	15
7.	Limestone,light colored,crystalline,becoming earthy in lower part.....	8
6.	Dolomite,dark gray,bituminous,of nodular and heterogeneous structure,with irregular seams of carbonaceous matter.....	10
5.	Limestone,variable in color,in flaggy layers with nodular surface.....	6
4.	Limestone,ash colored,fine grained,in layers 4 to 8 inches thick,$CaCO_3$ content 95%...	3
3.	Limestone,dull.....	8
2.	Limestone,dark gray,bituminous,nodular. The nodules are coated with a dark film of shaly,bituminous matter.....	5
1.	Limestone,light colored,porous,separating into thin slabs with uneven surface.....	10
		124

The most westerly exposure of Fiborn limestone is five miles north of Whitedale,where a gray to buff,lithographic limestone is exposed to only about 1 foot in height. An analysis gives 89.76% $CaCO_3$.

From its relation to the overlying and underlying formations at other points in the Upper Peninsula,the Fiborm limestone should be exposed somewhere in the arc from Indian Lake to the mouth of Sturgeon River,continuing under the waters of Big Bay de Noc and Green Bay to Door Peninsula in Wisconsin,where it should appear above the Virgiana barrandei mayvillensis zone in the outcrops along the roadside six miles west of Sturgeon Bay. At the latter

place,however,instead of the strata posessing the characteristics of the Fiborn,there occur rocks which Chamberlin has called the Byron beds,and considered them to be Niagaran in age. They are compact, cream colored to light gray limestones,fine grained and lithographic in texture. At the type locality near Byron,Wis.,they contain Leperditia fonticola in great numbers tho elsewhere they are practically destitute of fossils. It is thot that the lower part of the these beds as defined by Chamberlin,or the beds immediately overlying the Virgiana barrandei mayvillensis zone as defined by Savage[22], is to be correlated with the Fiborn limestone of Michigan.

If the Byron beds of Wisconsin represent a continuation of the Fiborn limestone towards the west,there is reason to expect that in view of the general saucer-shaped character of this Paleozoic basin,there would be a like continuation of the formation to the east,as far as Manitoulin Island and possibly to the Niagaran Falls region,but as far as known the outcrop at Dickinsons quarry on Drummond Island in the most easterly exposure.

Describing the Silurian section on Manitoulin Island,Williams states,that above the Cataract dolomite,the basal member,as exposed south of Manitowaning at the eastern end of the island,is overlain by 27 to 60 feet of red,clayey shale which in turn is overlain by the Lockport dolomite of Niagaran age. It is possible that this reddish shale represents the shore facies of deposits that are the equivalent of the Fiborn. It seems more probable however,that at Manitoulin Island and eastward,the Fiborn limestone was removed by erosion in pre-Niagaran time as is suggested by the thinning of this limestone toward the east as seen on Drummond Island.

TABLE VIII.

Table of fossils from the Fiborn limestone.

Locality 1F1. Two miles north of Hunt's Spur.

Favosites favosus Goldfuss.

Paleofavosites aspera D'Orbigny.

Discoceras conoides Hall.

Bumastus cf.ioxus Hall.

Locality 2F1. Three-quarters mile north of Blaney quarry.

Favosites favosus Goldfuss.

Favosites forbesi var.

Camarotoechia?winiskensis Whiteaves.

Straparollus sp.

Locality 4F1. Fiborn limestone at Hendricks quarry.

Favosites forbesi var.

Actinostroma cf. tennuifilatum Parks.

Atrypa putilla Hall.

Atrypa delicatula n.sp.

Camarotoechia?winiskensis Whiteaves

Orthis flabellites Foerste.

Plectambonites cf.transversalis var..

Schuchertella cf.propinqua M.& W.

Schuchertella subplana (Conrad).

Spirifer cf.eudora Hall.

Leperditia sp.

Locality 5F1. Three- quarters mile north of Gould City.

Zaphrentis sp.

Camarotoechia?winiskensis Whiteaves.

Hebertella sp.

Orthis flabellites Foerste.

Strophonella sp.

Bellerophon sp.

Leperditia sp.

TABLE IV.

Table of Comparative Analyses.*

Analysis Number.	Location of quarry or deposit.	Name, thickness and character of bed.	Percent $CaCO_3$.
230	NE cor. Encampment d'Ours Island.	Light colored, fossiliferous limestone; top beds.	89.00
237	Marble Head, Drummond Island. Outcrop short distance north of quarry.	Ash colored, Acervularia limestone, 3 feet thick near lake level.	95.00
238	Same as above.	Five feet dark gray, bituminous, nodular limestone; 30 feet below Acervularia bed.	94.00
238a	Same as above.	Lowest beds in the Marble Head section.	52.00
395	Fiborn quarry.	Fiborn limestone, 18 to 30 feet thick, massive, grayish buff, lithographic, locally filled with disseminated calcite crystals.	94.95
396	Same as above.	Fiborn limestone, bottom magnesian stratum, 1 to 2 feet thick.	92.71
400	Hendricks quarry.	Top, white, crystalline, magnesian beds, 1 to 10 feet thick. Strata Nos. 23 and 24.	75.55
401	Same as above.	Fiborn limestone, stratum No. 22, 18 feet thick, grayish buff, lithographic, with disseminated calcite crystals.	98.22
402	Same as above.	Fiborn limestone, stratum No. 3, bottom of bed.	89.65
403	Same as above.	Test pit, stratum No. 21, upper part, 4 feet thick. From floor of main quarry.	96.16
404	Same as above.	Test pit, stratum No. 21, lower part, hard, white, crystalline limestone, 4 feet thick.	90.89

* Mich. Geol. Surv. pub. 21, ser. 17, 1915, pp. 284-308.

405	Same as above.	Test pit,stratum No.20, dark gray to buff,fine grained limestone,1 foot thick.	98.65
406	Same as above.	Test pit,stratum No.19,hard, white,thinly bedded,crystalline limestone,1 1/3 feet thick.	91.69
407	Same as above.	Test pit,stratum No.18,hard, white, crystalline dolomite, 2 2/3 feet thick.	57.63
408	Same as above.	Test pit stratum No.17, brownish,drusy dolomite, 5 3/4 feet thick.	56.87
409	Same as above.	Test pit,stratum No.16, earthy limestone,1 foot thick,just above floor of pit.	99.47
425	Bluff 1 mile N of Hunt's Spur,sec.6 T 42 N,R 12 E.	Fiborn limestone,gray,lithographic,disseminated calcite crystals,bluff 15 to 20 feet high.	96.82
671	Manistique quarry, White Marble Lime Co.,Manistique.	Upper,blue strata.	57.00
673	Same as above.	Lowest bed quarried,light buff,very crystalline, fossiliferous dolomite, 8 feet thick.	54.04
675	Marble Head quarry, secs.35 and 36,T 42 N,R 15 W.	Massive,yellowish white, mottled,crystalline dolomite,much like the Engadine dolomite,8 feet thick.	55.00
678	Same as above.	Specimens from NE side of quarry. Rock solid blue in color.	55.24
680	Blaney quarry, 2 1/2 miles N of Blaney junction.	Fiborn limestone,gray to buff,lithographic,26 feet thick.	95.87
681	Same as above.	Upper 10 feet of quarry, five different beds.	95.98

688	Same as above.	Second 10 feet, from top of quarry.	92.16
689	Same as above.	Floor of quarry, white, coarsely crystalline dolomite, 3 feet thick.	59.58
695	Road cut, 5 miles N of Whitedale, 40 rods W of SE cor. sec. 2, T 42 N, R 14 W.	Fiborn(?) limestone, gray to buff, lithographic, 3 feet thick.	89.76
696	Boyle's quarry, sec. 6, T 42 N, R 12 W.	Limestone, white, crystalline, 6 to 8 feet thick.	73.08
697	Same as above.	Limestone, white, crystalline, laminated, lowest bed quarried, 2 feet thick.	89.87

Detailed Stratigraphy of the Niagaran Series.

Smith[5] has proposed the name "Manistique series" for those rocks in Michigan heretofore considered as representing the upper portion of the "Niagara" as earlier defined. He includes in this series all strata lying between the top of the Fiborn limestone and the base of the Engadine dolomite. For the rocks included between the top of the Manistique dolomite and the base of the Monroe formation he proposes the name Engadine dolomite. In the Niagaran series, Smith also included the Hendricks dolomite and Fiborn limestone, formations belonging to the Alexandrian series and so older than the Manistique dolomite and Engadine dolomite members of the Niagaran, thus only the two latter members are of Niagaran age.

The most salient topographic feature of the Niagaran series almost everywhere it is exposed is its tendency to form an escarpment, or cuesta, facing west, north or east as the case may be. In Wisconsin this cuesta which includes the Alexandrian (lower Byron-Mayville beds) at its base, as in the upper peninsula of Michigan, is an upland of from 7 to 20 miles in width in the former state and 4 to 16 miles in the latter. It overlooks the Green Bay-Big Bay de Noc lowland, being characteristically developed east of Lake Winnebago and on Big Bay de Noc at Burnt Bluff. On Door Peninsula and Washington Island it rises to from 160 to 220 feet above Green Bay which is 100 to 144 feet deep. Continuing north to Garden Peninsula it forms the high, west-facing line of cliffs which continue with breaks to Drummond Island and farther east. With the possible exception of Chambers Island in Green Bay, which is seven miles west of the escarpment, there are no spurs, mounds or outlying masses along 99% of its front[14]

Stereogram of Eastern Upper Michigan, Showing Geological Structure from Surface to Sea Level.

Note the Prairie du Chien and Alexandrian-Niagaran Cuestas.

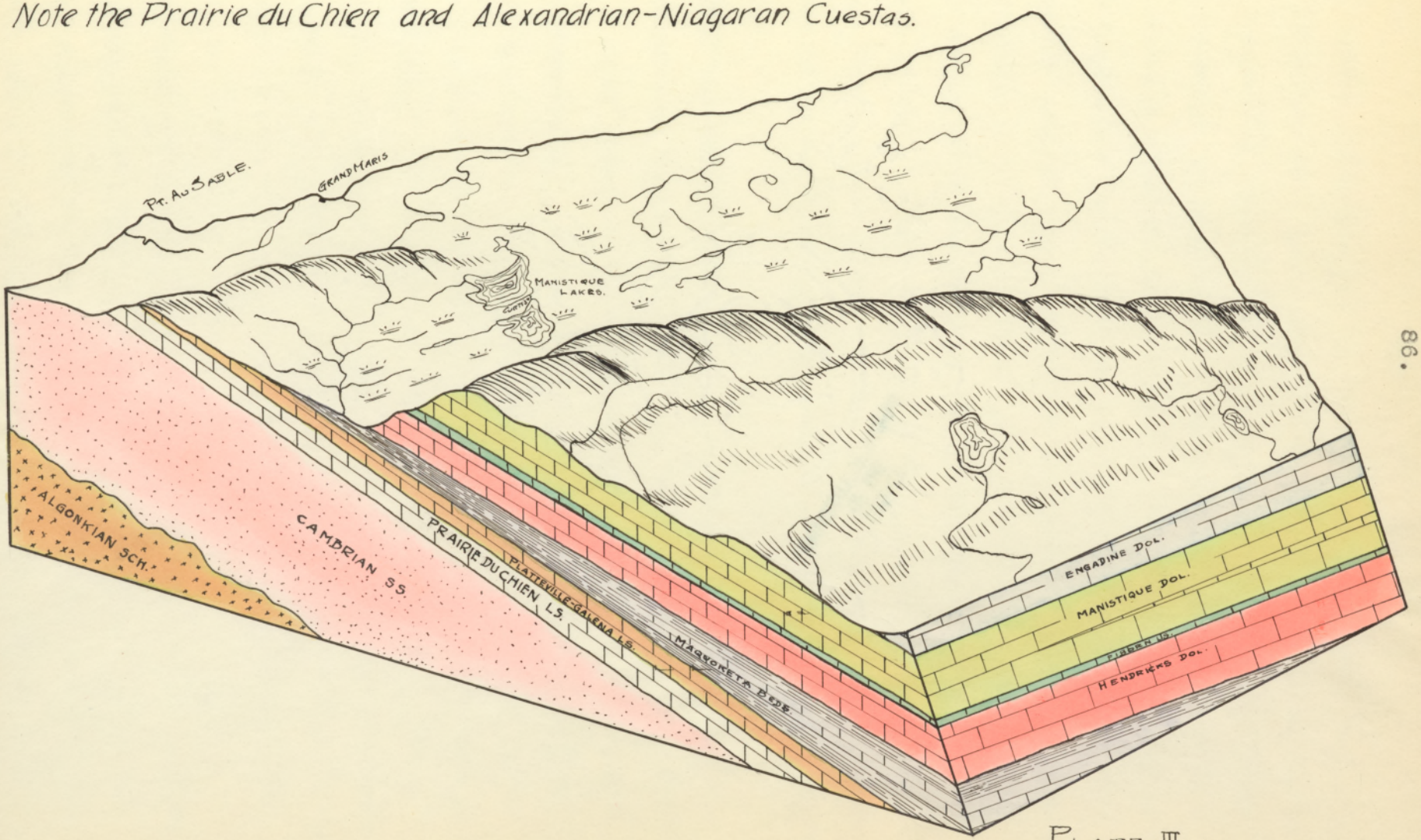


Plate III.

in the states of Wisconsin and Michigan. It is evident that but one agency,glacier ice,is capable of producing such profound simplicity in outline,and it is this agency which,acting thru the resistant Niagaran limestones,effected in such striking manner the soft,underlying Maquoketa shales and limestones.* Considering the Wisconsin and Michigan escarpments as a unit,they are broken by stream gaps at but three places thruout their extent in these states. These are (1) between Deaths Door and Garden Peninsula which is 30 miles wide and interrupted by several islands of varying size;(2) at Sturgeon Bay which cuts thru Door Peninsula and is 2 miles wide at the western face of the cuesta;(3) at St.Marys River which cuts thru the entire Paleozoic as exposed and has a maximum width thru the Niagaran of 12 miles. Whether these gaps in the otherwise continuous escarpment are due to glacial action or to stream erosion of pre-glacial rivers,it is not certainly known,but they seem to have been developed thru the combined action of both agencies. It is quite probable that the Manistique River-Indian Lake chain lies in a drift filled,pre-glacial embayment cut out at a place of low resistance in the cuesta.

The Manistique Dolomite Member.

With the exception of Garden Peninsula,the Manistique dolomite presents a north-facing cuesta to the south of which is a broad, gently sloping terrane that,west of Seoul Choix Point,extends to Lake Michigan. The Manistique cuesta is most prominent in the

* Martin thinks it possible that glacial erosion wore back as much as 10 miles of rock in producing this simplified escarpment.

bluffs on Garden Peninsula and in the eastern section in the hills north of Hessel,as well as on the southern side of Drummond Island. North of Manistique towards "Big Hill Bluff" on Indian Lake,there rises a succession of long gentle slopes and abrupt minor escarpments of gradually increasing altitude. At the latter bluff the member is terminated by the Manistique cuesta proper,east of which the transverse valleys are occupied by the Manistique,Mille Coquaine, Indian and other rivers. North of this cuesta occur sand plains or extensive swamps along the head-waters of the various rivers in Schoolcraft County. North of Blaney quarry,Gould City and Hendricks quarry,the Fiborn,either alone or with the Hendricks dolomite,forms the escarpment,at which places the Manistique is reduced to an undulating plain.

With the exception of local outcrops of Engadine dolomite* in the vicinity of Seoul Choix Point,the Manistique dolomite member occupies a broad arcuate belt parallel with the trend of the other Paleozoic formations. From just east of Nahma to Point Epoufette it borders the northern shore of Lake Michigan;east of the latter place it lies north of the Engadine member the entire distance to Marble Head quarry on the east side of Drummond Island. The thickness of this member is at least 320 feet and probably greater. Its relation to the underlying Alexandrian strata is well shown in the sections of strata exposed in Dickinsons,Seamans,and Marble Head quarries on Drummond Island.

Lithologically the Manistique dolomite consists of a great variety of dolomites and high magnesian limestones,all differing greatly in color,texture and structure. The color ranges from

* Stratigraphy of the Engadine dolomite not discussed.

pure white,light gray and buff,to dark gray,blue and brown;the texture is sandy,earthy,or finely to coarsely crystalline. The strata are generally massive except in the upper part of the formation where they are usually thin bedded. Many of the layers are fossiliferous,but some contain no fossils. After Stromatoporoids and Favositoid corals,Pentamerus oblongus is the most abundant fossil. Coral reefs are present west of Van's Harbor and at Fayette tho not well developed at either place. The best exposure of this formation is at Burnt Bluff on Big Bay de Noc,where the following section was measured:

Section of Strata exposed at Burnt Bluff.

		Thickness, feet.
8.	Dolomite,grayish,clayey,weathering into thin slabs,noted from top of bluff to three-quarters of a mile east.....	52
7.	Dolomite,siliceous,with scattered concretions, and with few fossils. (Vertical cliff)..	32
6.	Dolomite,brown,massive,iron stained,(Vertical cliff).....	28
5.	Dolomite,white,fissile,unfossiliferous.....	12
4.	Dolomite,brownish white,soft,upper Pentamerus zone.....	6
3.	Dolomite,grayish white,finely laminated,thin bedded,laminae show a ribbon structure, unfossiliferous. Layers vary in thickness from 1/8 to 3 inches,the color of the thicker strata grading from blue-gray below to buff above.....	22
2.	Dolomite,buff,thick bedded,crystalline,containing Stromatoporoids ranging in size from a few inches up to 2 feet in diameter. Lower Pentamerus zone.....	10
1.	Dolomite,white,thin,fissile,6 feet exposed,	

lower portion and adjacent strata covered by talus; to surface of water of Big Bay de Noc..... 118

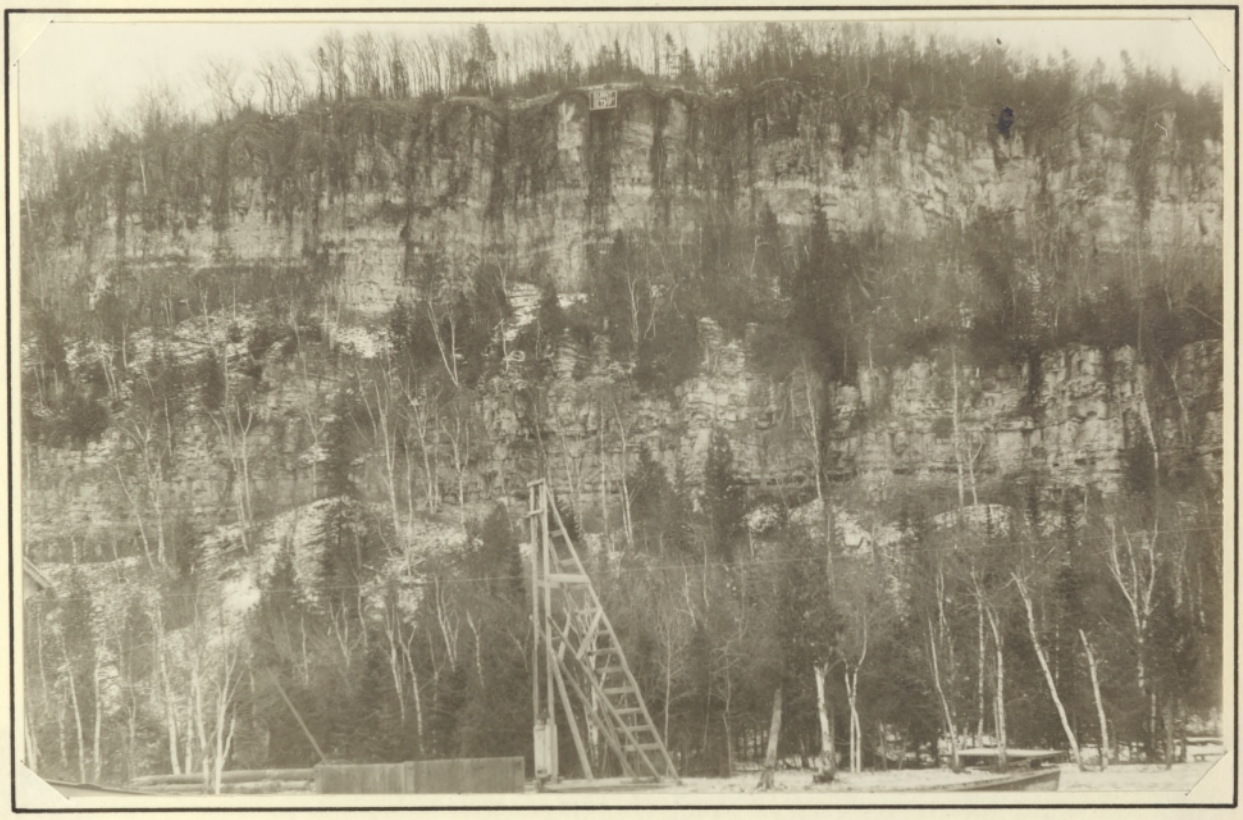
275

The sections given below are very similar to that at Burnt Bluff and show the general uniformity of strata of this member and the persistence of the Pentamerus and coral horizons.

Section of Strata exposed at Fayette. (Middle Bluff).

		Thickness, feet.
22.	Alluvium.....	1
21.	Dolomite, white, fissile.....	17
20.	Dolomite, buff, massive, characterized by numerous casts of Pentamerus oblongus.....	5
19.	Dolomite, buff, thin bedded, cherty.....	10
18.	Dolomite, bluish, compact, highly crystalline...	8
17.	Dolomite, white, compact.....	4
16.	Dolomite, buff, massive, cherty in the upper portion, with seepage planes indicated below by wavy lines, few fossils.....	20
15.	Dolomite, bluish, dense, grading into a buff zone above.....	9
14.	Dolomite, buff, dense, numerous casts of shells of Pentamerus oblongus.....	5
13.	Dolomite, buff, dense, mottled, with blue streaks above.....	9
12.	Dolomite, bluish, dense, laminated, grades to a buff above, breaks along partings into thin laminae which weather gray.....	11
11.	Dolomite, whitish, fine grained.....	1
10.	Dolomite, buff, coarse, cherty, with great numbers of Stromatoporoid and Favositoid corals	1

Fig.12.



Manistique dolomite at Burnt Bluff,Mich.

This is the best exposure of the formation and is one of the highest bluffs on Lake Michigan. Note the old Lake Algonquin shore-line about two-thirds up the face of the bluff.

Fig.13.

Manistique dolomite at Fayette Bluff,

Fayette,Mich.

Fig.14.

Manistique dolomite at Fayette Bluff,

Fayette,Mich.

A Pentamerus horizon occurs at the top followed by another half way down.

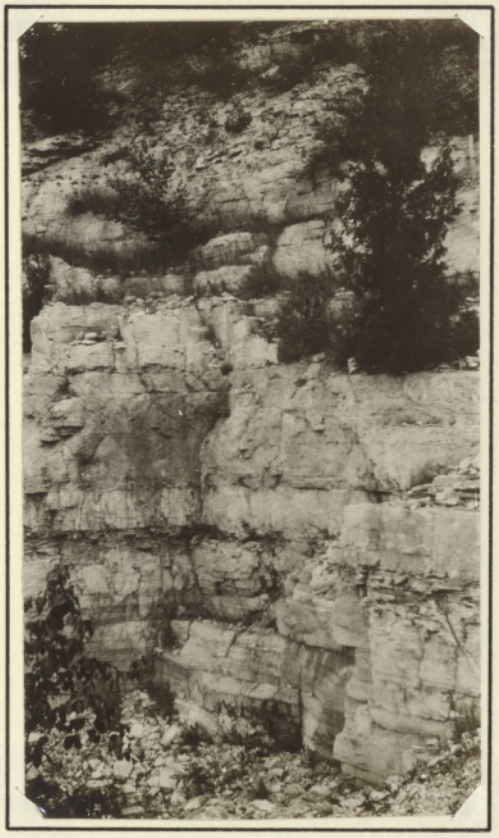
9.	Dolomite, buff, coarse, cherty, with few corals..	4
8.	Dolomite, buff, massive, unfossiliferous, alternating with dense fine grained strata, varying in thickness from 2 to 8 inches.	7
7.	Dolomite, bluish, thin bedded.....	2
6.	Dolomite, buff, coarse, with numerous casts of shells of Pentamerus oblongus.....	3
5.	Dolomite, bluish, thin bedded.....	1
4.	Dolomite, buff, coarsely crystalline.....	2
3.	Dolomite, buff, cherty, coarse, with great numbers of Stromatoporoids.....	5
2.	Dolomite, bluish, thin bedded, flaking off in thin laminae and weathering grayish white; to surface of water.....	1
1.	Dolomite, whitish, dense, below water.....	3
		129

Section of Strata exposed on the north side of Garden Bay, west of Van's Harbor.

		Thickness, feet.
5.	Dolomite, white, weathers cream colored, in thin fissile layers, unfossiliferous.....	20
4.	Dolomite, gray, massive, with masses of Stromatoporoid, Syringoporoid, and Favositoid corals, numerous casts of shells of Pentamerus oblongus.....	8
3.	Dolomite, white, weathering yellow, unfossiliferous, fine grained, grades above to gray...	15
2.	Dolomite, gray, fine grained, massive, numerous casts of shells of Pentamerus oblongus..	30
1.	Dolomite, brown, coarse grained, weathers dark gray, to surface of water.....	5
		78

The upper stratum of white dolomite,No.5 of the above section,increases in thickness westward,and 1/4 mile east of Van's Harbor the lowest exposed strata is a whitish dolomite,fine grained and fissile.

Fig.15.



Manistique dolomite at Fayette Bluff,

Fayette,Mich.

Note massive character of strata.

Fig.16.

Manistique dolomite at Marblehead quarry,

Marblehead,Mich.

TABLE IX.

The following fossils were collected from the Manistique dolomite:

Locality 1M1. From the Fayette-Burnt Bluff exposures.

Clathyrodictyon cf.vesiculosum N.& M.

Clathyrodictyon sp.

Clathyrodictyon sp.

Halysites catenularia (Linnaeas).

Omphyma verrucosa R.& C.

Favosites favosus Goldfuss.

Zaphrentis sp.

Zaphrentis sp.

Camarotoechia?winiskensis Whiteaves.

Pentamerus oblongus Sowerby.

Schuchertella sp.

Diaphrostoma niagarense Hall.

Hormotoma cf.subulata (Conrad).

Discoceras conoides Hall.

Illaenus sp.

Locality 2M1. From bluffs and field exposures to the west of Van's Harbor.

Clathyrodictyon sp.

Diphyphyllum huronicum Rominger.

Favosites favosus Goldfuss.

Favosites venustus (Hall).

Halysites catenularia (Linnaeas).

Syringopora retiformis Billings.

Atrypa reticularis (Linnaeas).

Dalmanella elegantula Dalman.

Pentamerus oblongus Sowerby.

Liospira sp.

Discoceras conoides Hall.

Locality 3M1. From field exposures sec.29,T 42 N,R 12 W.

Alveolites undosus Miller.

Cystiphyllum niagarense Hall.

Favosites favosus Goldfuss.

Halysites catenularia (Linnaeas).

Heliolites subtabulatus (McCoy).

Syringopora sp.

Thecia major Rominger.

Zaphrentis sp.

Zaphrentis racinensis Whitfield.

Zaphrentis sp.

Orthis flabellites Foerste.

Pentamerus oblongus Sowerby.

Spirifer sp.

Locality 4M1. From field exposures 200 yards north of Hunt's Spur.

Blotherophyllum caespitosum Rominger.

Favosites favosus Goldfuss.

Favosites venustus Hall.

Locality 5M1. From Marblehead Quarry.

Alveolites cf.undosus Miller.

Orthis flabellites Foerste.

Pentamerus oblongus.

CORRELATIONS AND GENERAL CONCLUSIONS.

The result of the work as outlined in the preceeding pages shows that the following two correlations can be made between the rocks of Northern Michigan and those of Wisconsin. It has been shown that the limestones and shales of the Cincinnatian series of the former state correspond in age to the Maquoketa (Richmond),and that they are overlain by the Edgewood member of the Alexandrian series which is older than the Cataract,according to Savage. This writer adds that the Sexton Creek limestone,next younger than the Edgewood,is probably to be regarded as the time equivalent of the Manitoulin member of the Cataract formation on Manitoulin Island. No typical Sexton Creek (Brassfield) fossils have been found either in Wisconsin or Michigan,but it is probable that the Fiborn limestone as well as the lower portion of the Byron beds,represents a transition phase succeeding Edgewood time. Williams points out that the Utica is absent on Manitoulin Island. It has been shown that the Richmond as developed in the eastern United States is not to be correlated directly with the Maquoketa,since it belongs to a different geological province,tho it is probably a time equivalent. None of the Lorraine fossils of Manitoulin Island are found in the exposures of the Cincinnatian farther west. On the contrary,there is a resemblence of the latter to those of the Maquoketa of Wisconsin, as will be seen from the list given on page50. It is thot that the strata of the Cincinnatian series in Michigan are a direct continuation of the Maquoketa beds of Wisconsin,with which rocks it is thot that the Cincinnatian strata in Michigan are to be correlated.

The presence of Virgiana barrandei mayvillensis and V. barrandei major in the Hendricks dolomite clearly indicates that this formation is to be correlated with the upper Mayville limestone of Wisconsin. In the latter state where the Alexandrian has been studied by Savage[22], that part of the Mayville limestone lying below the Virgiana zone, has a thickness of about 149 feet and is the equivalent in age, of the Edgewood formation of the Alexandrian series as developed in Illinois. Savage has since shown that the Virgiana zone of the upper Mayville limestone is to be correlated with the Virgiana barrandei zone of the Bescie River[44] formation of Anticosti Island. Since, in Wisconsin, the middle part of the Mayville beds pass without an apparent sedimentary hiatus into the Virgiana zone; and in Illinois Platymerella manniensis, a near relative of Virgiana, occupies a similar stratigraphic position, the top of the Edgewood formation in these two states has been drawn at the top of the Virgiana-Plattymerella horizons. The lower part of the Byron beds in Wisconsin, which also contain a part of the Virgiana zone, is of Edgewood age, and is considered older that the Sexton Creek formation of Illinois. Evidence has been presented in an earlier chapter suggesting that at least the lower portion of the Byron beds is the southern and more magnesian continuation of the Fiborn limestone which occupies a similar position with respect to the Virgiana horizon, and thus is of Edgewood age. On the basis of Virgiana barrandei mayvillensis, Atrypa putilla, and Homeospira subcircularis, the Hendricks-Fiborn beds of Michigan can be correlated with the Mayville limestone of Wisconsin and therefore correspond in age with the Edgewood limestone of Illinois and Missouri, and with the Bescie

River formation of the Anticosti region.

In the list of fossils collected from the Manistique dolomite member of the Niagaran series it will be noted that Camarotoechia?winiskensis,a brachiopod described by Whiteaves from the Winisk River,a tributary on the west side of Hudson Bay,has also been found at Fayette. This fossilhas also been found in both the Hendricks and Fiborn members of the Alexandrian series. These facts not only indicate that an arm of the sea was Probably connected with the Hudson Bay region during Edgewood time,but that the Hudson Bay region was connected with the Niagaran sea to the south at a later interval,thus allowing the migration of some of the species which had survived the Alexandrian. The finding of this specimen changes considerably previous ideas on the extent of the northern seas in mid_Silurian time.

Descriptions of New Species.

Atrypa delicatula

DESCRIPTION:- Shell small,width about equal to the length,elongate,sub-ovate in outline,hinge line about one-half greatest width, cardinal extremities rounded. Dimensions of an entire specimen are: length 6.5 mm,width 7 mm,convexity 2.5 to 3 mm. Pedicle valve the more convex,umbo narrow,apex acute,delthyrium open,mesial sinus originating as a flattening of the umbonal region becoming broader tho shallower as the front margin is approached,marked by two simple, well-rounded plications extending from beak to anterior margin.

Brachial valve depressed-convex in the umbonal region becoming more pronouncedly convex in the middle region,beak pointed and incurved slightly beneath that of the pedicle valve,the sides of which slope away at an angle of about 110 degrees;a broad,shallow sinus is present in the umbonal region which changes farther anteriorly into a slight fold the latter occupied by two well-rounded plications.

Surface marked with 12 to 20 radiating plications and with fine concentric growth lines.

HORIZON:- Alexandrian series (Hendricks dolomite and Fiborn limestone) in northern Michigan.

LOCALITIES:- Hendricks quarry,Fiborn quarry,etc.

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